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Ecology of the California Ground Squirrel on Grazing Lands

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INTRODUCTION

The impact of rodent use on the fluctuating crop of annual vegetation in the foothill ranges of California entails vast losses to the livestock industry to which these areas are mainly devoted. Recognition of this loss led to the conception of the present cooperative study as an integrated part of the larger problem—the development of the most economical management practices for the foothill ranges.

Of the many rodent species which compete with livestock for range forage in the foothill belt, the majority are of minor importance because of small size, low populations, or food preferences different from those of stock, with perhaps even some beneficial bearing. Much of the damage to the ranges is caused by a few species, and perhaps paramount among these is the California Ground Squirrel (*Citellus beecheyi*), the subject of this report. Throughout the far western states ground squirrels of the *Citellus beecheyi* complex are among the most destructive of native rodents. In most parts of California control measures have long been vigorously practiced wherever the squirrels threatened the existence of cultivated crops, with the result that these rodents have been held in check or locally exterminated. But on range lands the mar-

gin of profit to be gained by their elimination is much smaller and control is more difficult; in some situations it is unprofitable.

The present study was limited to one locality, the San Joaquin Experimental Range 23 miles northeast of Madera in oak-digger pine woods of the lower foothills on the west flank of the Sierra Nevada. The locality is fairly typical of the entire foothill belt almost encircling the Great Valley of California. The present findings should in general apply throughout this belt, but minor differences resulting from variations in altitude, soil and plant types, and natural histories of the several geographic races of squirrels might be expected.

The objectives of this ground squirrel study were to determine the kinds and amounts of food taken by the squirrels from a forage crop of which the quantity and composition were accurately known through measurements; to measure the populations of squirrels and to trace their changes throughout the year and over periods of years; to determine the factors limiting or influencing the population, including the roles of the several squirrel predators; to find out as much as possible concerning the habits and natural history of the squirrels.

An extensive literature already exists regarding the classification, distribution, habits, and means of control of this and related species of ground squirrels. An especially important paper is that of Grinnell and Dixon, 1918, *Natural History of the Ground Squirrels of California,* in which much detailed information concerning the ecology of this and other ground squirrels is set forth. Howell (1938) in his *Revision of the North American Ground Squirrels* brought the classification up to date, redefining the ranges of the several geographic representatives of this species.

More recently several intensive ecological studies have been made on this species of ground squirrel in different parts of its range. Storer, Evans and Palmer (1944) in a study at Bass Lake, California, only 20 miles from the Experimental Range but at a higher altitude under different ecological conditions, live-trapped and marked ground squirrels and other rodents in 1938 and 1939 on a four acre area. The numbers of squirrels dealt with were small but the findings, particularly in regard to seasonal dormancy, are of significance in affording sharp contrast with data from the Experimental Range for the same two years. Another important paper is that of Evans and Holdenreid (1943), *A Population Study of the Beechey Ground Squirrel in Central California.* The population dealt with was of the race *beecheyi* subspecifically distinct from *C. b. fisheri* of the present report, and the locality is Calaveras Reservoir, about 120 miles west and a little north of the Experimental Range. This latter study was pursued primarily from the viewpoint of plague relationships, but also touched upon the feeding habits. Live-trapping and field observations were carried on in 1940, 1941, and early 1942, but for only part of each year. Some of the findings set forth are at variance with those of the present study.

The most detailed field study of this, or perhaps any mammal, is that of Linsdale (1946), *The California Ground Squirrel.* It is based mainly on narrative field notes of 21 different observers over an eight year period at the

Hastings Wildlife Reservation, about 115 miles southwest of the Experimental Range. Mannerisms and behavior are particularly stressed, and the molts, reproductive physiology, anatomy and parasites are most thoroughly dealt with. However, but little effort was made to determine the effect of the squirrels on the vegetation. Comparatively few data were obtained on predation, and live-trapping was on a smaller scale than in the present study.

Figures and statements in Linsdale's paper in many instances indicate or suggest important ecological differences between the population studied by him and that of the Experimental Range in such matters as feeding, season and extent of dormancy, and critically limiting factors which determine numbers and local distribution. Differences are to be expected since distinct geographic races in contrasting environments are involved. An understanding of such geographic variation is essential in dealing with this rodent successfully over its entire range.

The present study was planned and carried out under the direction of Everett E. Horn of the U. S. Fish and Wildlife Service, to whom the writer wishes to express appreciation for help in many ways. The work was done in cooperation with the U. S. Forest Service, California Forest and Range Experiment Station. Thanks are due members of the Experimental Range staff: Dr. Harold H. Biswell and Jay Bentley especially rendered valuable assistance and advice from time to time in connection with problems involving the forage. Howard Twining, Daniel F. Tillotson, and John E. Chattin identified material in pellets of raptors and "scats" of predators. Many persons helped from time to time with the field work, and of these Freeman Swenson and Frank Hagarty are due especial mention for their continued interest and initiative.

A detailed account of the economy and ecology of the general area has already been set forth, describing the topography and soil (Talbot, Nelson and Storie, 1942), vegetation, livestock relationships (Wagnon, Guilbert and Hart, 1942), and wildlife (Horn and Fitch, 1942). The area is in rolling, wooded foothills, characterized by shallow, rocky soil with granite outcrops, and small areas of grassland interspersed with brush, Digger pine, blue oak, and interior live-oak.

HISTORY AND METHODS

The rodent enclosures, from which data concerning the amount of vegetation destroyed by squirrels were obtained, were installed at the San Joaquin Experimental Range in 1935. Other field work was begun the last week of March, 1938. Relatively few squirrels for the population study were trapped in 1938, as only a few miscellaneous traps of ineffectual types were then available. For part of 1939, trapping was carried on with make-shift traps which were not wholly satisfactory, and the 80 acres was first covered by May 1939. In 1940, traps were available in quantity, and field assistance for this and other projects was rendered by several helpers, Freeman Swenson, Frank Hagarty, Bernard Mitchell, Jack Ramley, and Raymond Sharp. In 1941, during the writer's absence, from March through September, trapping was carried on successively by Freeman Swenson, Henry Hjersman, and

Lowell Adams. In 1942, after the writer had left for military service early in February, trapping was continued through May by Frank Hagarty. In 1946 the area was trapped by the writer during the period January 13 to April 13. Data are thus available for three full years, 1939, 1940, and 1941, with two more years' data, 1942 and 1946, for the late winter and spring period of maximum ground squirrel activity and more meager data for 1938. During the course of this study, on the 80 acre area where live-trapping was carried on, 1,552 squirrels were captured a total of 15,936 times. Records of captures were distributed as follows: 1938—377, 1939—2874, 1940—5289, 1941—5072, 1942—1620, 1946—704. Numbers of animals caught each year were as follows: 1938—182, 1939—572, 1940—643, 1941—625, 1942—353, 1946—226.

No record was kept of the number of "trap days" involved, but usually around 200 traps were set several times a week. Usually only half the area was trapped at one time, in alternate, bi-weekly intervals. During each trapping period one or several traps were readily accessible to every animal on the area. Trapping success depended less on the actual number of traps used than on their careful placement at points where the animals were constantly tempted, their adjustment and mechanical efficiency, and the amount of disturbance by cattle, birds, ants, and other animals that might steal the bait or trip the traps. Placement at random or spaced in a grid system over the area would have caught very few squirrels, as it was observed that these animals were shy of traps encountered afield during their foraging, and usually gave them only passing notice. Traps set on burrow mounds or at loafing places where squirrels habitually spent their time, were most apt to be successful, but often a capture was preceded by hours of maneuvering on the part of the squirrel, too cautious to enter immediately. While some individuals were readily trapped, others were so shy that they avoided capture for long periods though traps were almost constantly available to them. Several are unrepresented in the records for an entire calendar year though trapped at the same burrow system in both the year preceding and the one following the lapse. The maximum number of captures recorded for any one squirrel were 117, these extending over a 20 month period. This was a male squirrel, and several other males were each caught more than 100 times, but 80 captures was the maximum recorded for any female. A few crippled individuals, evidently handicapped so that they could not forage normally, became unusually persistent repeaters. One adult female, which had broken its leg, was caught 19 times during a month.

The 80 acre area where live trapping was carried on was grazed by cattle from January through August and was stocked at the rate of one head per ten acres. Utilization was classed as moderate to close. The area was rectangular, about half a mile long, and a quarter mile wide.

The box traps used were constructed of half inch mesh galvanized wire, open at one end, and tripped by means of a pendulous trigger (Horn and Fitch 1946:222). Bait was a mixture of wheat and milo maize, which was scattered in a trail from the outside into the trap beneath and behind the trigger. In the winter, traps were set in the open on burrow mounds, and were baited in the morning before the squirrels began to feed. In summer, sets

were made in the shade of rocks, trees or bushes in spots where the squirrels were accustomed to stay, and traps were protected from the sun by covering with strips of wood and bark, or "cow chips." They were usually sprung during the heat of the day and were set and baited during the early morning and late afternoon for the two daily foraging periods of squirrels at that season.

In 1938 the squirrels trapped were marked with numbered aluminum tags and colored celluloid disks in each ear, but so many of these were lost that the system was abandoned, and marking was accomplished by toe clipping. On each animal two toes always on different feet, were amputated, and 121 different toe combinations were possible (the rudimentary thumbs were not used). These series of toe formulas were used repeatedly in combination with different key ear marks, eleven in all.

At each capture the identification formula, date, sex, weight, breeding condition, and location of the animal were recorded. Location was estimated in terms of distance in feet, and direction of the nearest landmark, usually a tree, bush, rock, or post. These named landmarks were well distributed over the area so that usually any point to be recorded was within 100 feet of one.

Study of the feeding habits was commenced in March 1938 and continued throughout the duration of field work, but few observations were made in 1946. The bulk of feeding records were obtained from field observation of a few individual squirrels which could be closely observed, but these were well distributed in different types of situations in various parts of the Range. Miscellaneous feeding records were gathered as opportunities arose, from stomach or cheek pouch examinations, or from direct observation on feeding.

Most feeding records were obtained from relatively tame squirrels conditioned to the presence of humans, and observed either for an entire day at a time, or through a main foraging period. Under the most favorable conditions every item taken during a feeding period could be recorded, for instance when a squirrel was feeding at close range, mainly on one kind of fairly large food item, such as acorn, or fruits of filaree or tarweed. At other times, when the food included a variety of minute items, it was impossible to determine just what was taken, even by close range observation.

Census methods.—Counting the squirrels on any extensive acreage was found to be difficult, mainly because of the uncertainty as to how many were underground at any one time. Much time was spent in making counts of the numbers seen per minute while walking across different pastures of the Range. Through use of comparable counts made on the 80 acre trapping area with its approximately known population, census of the entire Range was attempted. There was no consistency in the counts obtained, and it appears that a very large sample would be required for a statistically accurate census. Counts were made only on days which were favorable to squirrel activity, and only during parts of the day when they were thought to be out in maximum numbers. Differences in terrain posed the most serious obstacle in obtaining comparable counts between different areas. Where brush, trees, rocks, and irregularities in the ground surface obscured the view, fewer squirrels could be seen than in open areas. The trapping area was relatively open compared with the

Range as a whole, and since its population was used as a standard of comparison the numbers computed from counts on other areas are apt to be erroneously low.

On each of the pastures where counts were made, squirrels were unevenly distributed. Concentrations occurred at few places with much sparser populations intervening. In the mile or half-mile walk across a pasture, often several squirrels were seen within a few seconds and these might be the only ones seen.

In this locality February and March are the best months for making counts; then there is no dormancy, and squirrel foraging is concentrated within a few hours during the middle of the day, so that the whole population is apt to be active at the same time. The vegetation is still low so that the animals can be readily seen at this time of year. In summer counts the number per minute is consistently lower even though the actual population is much greater, having been increased by the annual crop of young. Variation among individuals in time of activity during the increased hours of daylight, high vegetation obstructing view of the counter, and tendency of the squirrels to stay in sheltered places, and to forage in trees, are all factors which prevent one from seeing so large a percentage of the number present. These same factors are variables which introduce a margin of error in comparing the counts from any two areas.

In an attempt to sample rapidly squirrel populations of relatively large areas several hundred counts of numbers seen per mile were made from an automobile, driving at constant speed of 20 miles per hour over various roads in Madera County range lands. Examination of these data indicates that the samples are inadequate. A road ran diagonally for the length of the trapping area a distance of .54 miles, and a total of 74 counts were made on this road, all in the breeding season when the entire population was active, and all at times of day when squirrel activity was judged to be at its maximum. The number of squirrels per count averaged 11.6 but varied from 3 to 27. Though the counts were made in 5 different years, change in the squirrel population itself was not an important cause of the differences; trapping records indicate that the active population was at all times either between 250 and 300, or near these extremes. Counts were made in nine different months and the number of counts per month varied from 4 to 18. To summarize these records, the average of four counts was 18.2 squirrels; of five counts, 9.2; of six counts, 15.2; of eight counts, 16.2; of fifteen counts, 10.9; of eighteen counts, 10.1.

These figures suggest that for this distance and population density at least 10 counts would be necessary to obtain a reliable average. As this stretch of road was .54 miles, the average 11.6 squirrels seen represent 21.5 per mile where a population density of two to three per acre was present. On this basis one squirrel per acre would be represented by a count of about eight or nine per mile—other things being equal. On the trapping area there were occasional oak trees and rock outcrops but for the most part the view was unobstructed, and squirrels were often counted at a distance of 100 yards or more. In rocky or brushy or wooded terrain, or with high vegetation obscuring the view, the ratio of number seen to those actually present would be lower.

In an attempt to check the population of the trapping area as determined by total numbers trapped, use was made of the familiar "Lincoln Index", based upon recapture of marked animals—the ratio among animals taken during a given period, of recaptures from a previous period:

$$\frac{\text{Total population}}{\text{Number caught in first period}} = \frac{\text{Number caught in second period}}{\text{Number caught in both first and second periods.}}$$

Deaths or movements off the area between periods would affect the figure obtained, but would not be an important source of error in month to month computations. However, two peculiarities of the squirrel population studied rendered this standard census method almost worthless by distorting the ratios obtained. Varying appetite for bait among individuals, and differences in wariness to the traps caused some to repeat frequently while others persistently evaded capture, tending to give an erroneously low population figure. Retirement into, and emergence from dormancy, occurring in varying degrees through most of the year, likewise produces a false ratio of repeaters to the entire population for any given sample period. The margins of error caused by these several factors cannot well be evaluated or separated, but their effect is apparent in the erratic fluctuations of the figures obtained. When a two months period was used as the census time, the resulting figure averaged 129 per cent of that obtained with a one month census, the difference being due to movement and dormancy. Separate computations were also made for different sex and age groups. The figures in Table 1 are based on a one month census period immediately followed by a month post-census. In many cases the figure is almost certainly below the actual number, due mainly to the error caused by individual difference in tendency to enter traps or to avoid capture. Inclusion of this table is intended to show limitations of this census method where varying wariness, trap experience and bait addiction, and habits of different individual animals are involved.

TABLE 1.—Distorted census figures obtained from trap ratio of repeaters to others on 80 acres.

	1939	*1940*	*1941*	*1942*
January	262	277	245	282
February	217	279	225	262
March	221	203	197	190
April	793 (249 adults)	387 (191 adults)	308 (165 adults)	135
May	535	462	375	
June	479	399	388	
July	474	304	304	
August	289	423	234	
September	236	301	227	
October	223	258	197	
November	181	220	163	

Young squirrels newly emerged above ground do not enter traps as readily as adults and may be little attracted by the grain bait, as they seem to prefer

natural foods of succulent kinds. It has long been recognized by those engaged in control operations that poisoning just after the young emerge is apt to yield poor results. Therefore the young are not represented in their true proportions in the April and May catches, and the census figures obtained for those months are correspondingly low.

The actual numbers of squirrels present during the breeding season are perhaps best indicated by the number of individuals actually trapped during the period January, February, March and April, when the whole adult population is active and the situation is not complicated by presence of small young. Even in the figures obtained at this season there is some margin of error for certain individuals which are missed even during intensive trapping, and there is movement to the study area of new individuals, in the constant gradual shifting that occurs. Also, some are trapped within the boundaries of the area, which range mainly outside it. These last two factors tend to make the numbers trapped erroneously high for a representation of the true population present. At other times of year, varying dormancy of part of the population, and the rapidly changing numbers of young still further obscure the true population density. It can only be estimated from the relative numbers of different sex and age groups, and from the percentage of the breeding adult population represented. Allowance must be made for expected normal mortality as indicated by reduction from one year to the next of any given group of individuals.

Even direct counts probably do not give a true ratio of young to adults, since the young are less conspicuous and after first emerging sometimes retire into the burrows again for periods of days. Several attempts to determine dispersal and causes of loss, in newly emerged litters failed because the young seen and counted at a burrow on one day usually could not be located there on later dates, and must have come above ground only occasionally during the first week or two after emergence.

FEEDING

Quantities consumed.—In the past the feeding has been less thoroughly studied in its quantitative aspects than it has qualitatively. The kinds of food taken differ according to season and locality, while the amount required to maintain an animal is doubtless fairly constant over any long period, though subject to variation due to the age, sex, and physiological state of the individual, and the palatability and nutritive value of the kinds of food used.

Linsdale (1946:222) stated "In evaluating the effects of squirrels on forage crops it is not enough to determine that certain kinds of plants are eaten. Nor can the effects be computed correctly by determining the amount of food contained in the stomach at any one time or taken in one day. These are not suitable bases for computation, partly because they change continuously and irregularly."

The variation mentioned by Linsdale was also apparent in the present study and it is evident that no precision measurement of squirrel damage to the forage crop can be made. The forage crop is affected by so many other variables that it is difficult to identify the effect of ground squirrels. Never-

theless, it is believed that in general the extent of damage to the forage can be determined by use of experimentally controlled plots, direct observation of the quantity and kind of vegetation used by feeding squirrels at different seasons, and the determination of the squirrel population.

Grinnell and Dixon (1918:629-630) stated that in feeding experiments in captivity: "Fifty grams . . . of green alfilaria was found to be the average daily ration for an average-sized squirrel. In cases where all food had been withheld from the squirrels the previous day, the greatest amount of succulent alfilaria, the favorite food of the squirrel, consumed in one day was 80 grams . . ."

"It is believed by us that two ounces of green forage or one-half ounce of dry grain is an average stomach-full for an average sized California Ground Squirrel and that two stomach-fulls represent a day's ration."

Storer, Evans, and Palmer (1944:189-190) obtained somewhat similar figures for the food consumption of the ground squirrel from purely theoretical calculations. Quoting Kleiber that the food requirement of a mammal is proportional to the ¾ power of its body weight or the "metabolic body size", they estimate the metabolic body size of a ground squirrel: Average weight .5 kg.; metabolic body weight = $.5^{¾}$ kg. = .6 kg. As standards they quote Smith that 161 gram laboratory rats ate 14 to 15 grams of stock ration (dry weight 13 grams) daily, and Ranson that 30 gram *Microtus agrestis* daily ate 19 grams of combined herbage, roots, and cereal (dry weight 5.7 grams). The laboratory rat and *Microtus* were calculated to consume respectively 52 and 81 grams per kilogram of metabolic body size. On the same basis ground squirrels were computed to consume either 31 or 49 grams daily of air dry food weight (depending whether the *Microtus* standard, or the rat standard was used). The authors state that the higher figure may more nearly approximate the natural "average rodent diet"; "but both diets probably are below average in quantity because animals in captivity are thought to expend less energy than those free in nature". It is of interest that the lower figure of 31 grams per squirrel per day closely approximates Grinnell's and Dixon's estimate of one ounce (= 28.35 grams—"two half-ounce stomach-fulls) of dry grain per squirrel per day.

Field observations and laboratory feeding in the present study have indicated, however, that these estimates are too high. To consume an ounce, or about 30 grams dry weight per day (the approximate figure accepted by Grinnell and Dixon, and less than the lower figure mentioned by Storer, Evans and Palmer) a squirrel feeding on new succulent vegetation of high moisture content, 80 per cent or more, would have to consume at least 150 grams of actual food. Probably this amount is rarely, if ever, taken in a day.

In the summer of 1946, feeding experiments with dry wheat were made with nine different squirrels of both sexes—adults, and young of the year which had already attained the size of small adults. For 90 squirrel days of feeding, an average of 22.5 grams per squirrel per day was taken, but for different animals the average daily consumption varied from 31.1 to 12.4 grams. These tests were made in mid-summer when the long daylight hours promoted maximum intake of food.

Two other squirrels in confinement were fed entirely on natural foods of the same kinds being used by those in the wild. The amount taken each day was determined by weighing the uneaten residue and subtracting this from the amount offered; control samples were kept to check any weight loss by evaporation, and corrections of a few percent were applied to the amount decreased, to obtain a more accurate figure of the amount actually eaten. Ordinarily on each day only one kind of food was offered, thus relative positions of different foods on the scale of preference were checked. The records extended over the period March 14 to May 8, 1941. During this time weights of the two animals were recorded at the beginning and ending of each day's feeding and fluctuated between 445 and 576 grams, but with no consistent downward or upward trends. For 53 days' feeding the kinds and amounts taken were as recorded below:

TABLE 2.—Quantities of natural foods eaten by ground squirrels.

Kind of food	Number of meals	Average weight of meal	Estimated percentage of water	Estimated dry weight
Broadleaf filaree ..heads	20	66.95 gm.	86 %	9.4
Broadleaf filaree ..leaves	8	44.2 gm.	87 %	6.3
Ground lupine .....plants	8	67.8 gm.	85 %	10.2
Layia .....flowers	4	63.2 gm.	75 %	15.8
Goldfields .....flowers	2	100.0 gm.	75 %	25.0
Birdseye gilia .....flowers	2	46.3 gm.	75 %	11.5
Slender oat .....florets	2	33.5 gm.	71 %	9.7
Blue-dicks .....flowers	2	23.5 gm.	75 %	5.9
Popcorn flower ....plants	2	32.9 gm.	85 %	4.9
Spanish clover .....plants	1	38.3 gm.	80 %	7.7
Acorn	2	10.0 gm.	41 %	5.9

Though all the foods listed above are extensively used by squirrels under natural conditions, several were taken sparingly by these caged individuals. When mature heads of soft chess were offered, both squirrels ignored them and fasted till the following day when other food was made available. For the better liked kinds of food, heads of filaree and plants of lupine, the amount recorded as eaten daily (average 67 grams) probably approximates the quantity taken under natural conditions.

When squirrels are feeding upon succulent green stuff, sixty to seventy grams ordinarily makes up the amount consumed in a day's foraging, though occasionally this may be exceeded. During the winter, when such material comprises the diet, only one daily foraging period is the rule; little feeding is done before mid-morning, and most squirrels have retired for the day by mid-afternoons. Forty-six stomachs collected in the latter half of January 1941, when segregated according to hours of collection, showed progressively increasing weights for each successive hour.

Most of the squirrels in the 2-3 p. m. group had not yet completed their foraging day when collected.

TABLE 3.—Average weights of stomach contents at different hours of the day.

Hour	Number of stomachs	Stomach contents weight in grams (Average and extremes)
9–10 a.m.	4	7.0 (4.5–9)
10–11 a.m.	10	10.5 (7–17)
11–12 m.	10	14.7 (7–25)
12:50–2 p.m.	14	25.9 (19.5–40.6)
2–3 p.m.	8	45.9 (37.5–64)

In spring, as days grow longer and warmer, the foraging periods are less sharply circumscribed and lengthen until in summer there are two daily feeding periods with a resting period intervening. Amounts of food taken per squirrel are correspondingly increased. By late afternoon part of the morning meal is digested and the stomach is again filled to capacity. Since most of the squirrels during late spring and early summer are young or half-grown, having smaller stomach capacity than adults, the amount per squirrel per day eaten at this season may not much exceed the winter figure.

Direct observation of squirrels foraging under natural conditions and taking items of which weight and number could be accurately recorded, also showed that the amount taken in a day of feeding was variable. For several complete days of feeding, the items taken and their weights, as determined from duplicate samples collected on the spot, are shown below. The examples here presented are selected from a large number of all-day records, and are those for which weights can be most accurately estimated because relatively few kinds of items were taken and these were of relatively constant size. For each of the "squirrel days" recorded below, length of active day and periods of actual foraging are shown in Figure 11.

TABLE 4.—Kinds and amounts of food taken by foraging ground squirrels.

A. Young adult female, December 8, 1939

Kind of food	Number of items	Weight per item in grams	Gross weight in grams	Dry weight in grams
Red-stem filaree plants (rosette stage)	58	.26	15.08	2.05
Red-stem filaree leaves	1	.08	.08	.01
Broadleaf filaree plants (rosette stage)	71	.336	23.85	3.10
Broadleaf filaree leaves	107	.102	10.91	1.42
Popcorn flower leaves	22	.08	1.76	.26
Red brome plant	1	.10	.10	.01
Oat leaves	1	.01	.01	.....
Buckthorn weed leaves	1	.08	.08	.....
Fescue leaves	1	.002	.002	.....
Total food weight for the day			51.87	6.85

TABLE 4.—(*Continued.*)

B. Adult female nursing litter, April 21, 1939

Kind of food	Number of items	Weight per item in grams	Gross weight in grams	Dry weight in grams
Broadleaf filaree seeds	1521	.067	101.91	14.12
Ground lupine pods	112	.0955	10.70	8.03
Ground lupine entire plant	3	.44	1.32	.99
Popcorn flower nutlets	12	.086	1.03	.52
Clover leaves	1	?	trace	
Brodiaea leaves	several	?	trace	
Total food weight for the day			114.96	23.66

C. Adult male, June 30, 1939

Kind of food	Number of items	Weight per item in grams	Gross weight in grams	Dry weight in grams
Acorns	91	.21	19.11	11.36
Redberry berries	88	.14	11.29	5.65
Wedgeleaf ceanothus fruits	8	.25	2.00	1.00
Ripgut brome seeds	2	.0142	.03	—
Total food weight for the day			32.43	18.01

D. Same adult male, August 14, 1939

Kind of food	Number of items	Weight per item in grams	Gross weight in grams	Dry weight in grams
Acorns	13	3.8	49.4	29.3

E. Same adult male, September 14, 1939

Kind of food	Number of items	Weight per item in grams	Gross weight in grams	Dry weight in grams
Acorns	7	3.8	26.6	15.8

TABLE 4.—(*Continued.*)

F. Adult female, October 11, 1938

Kind of food	Number of items	Weight per item in grams	Gross weight in grams	Dry weight in grams
Yellow tarweed seed heads	901	.0375	33.79	8.55
Acorns (liveoak)	26	.5	13.00	9.00
Droppings of squirrel and rabbit	10	.3	3.00	3.00
Ripgut brome seeds	59	.0142	.84	.84
Total food weight for the day			50.63	21.39

Remarkable difference between individuals in amount of food taken is indicated. Sex and age differences and seasonal activity are evident factors. The adult male which was observed for the June, August and September records, was fat and sluggish, and did not wander far from his burrow, showing little inclination to feed. The female squirrel which took almost 115 grams of green stuff during one day in April may be typical of those lactating, which were observed to forage more persistently and voraciously than others. The young adult female which took nearly 52 grams of succulence in the course of a December day's feeding is thought to be representative of the entire population at that time of year.

If the figure of 70 grams of green feed per day per squirrel is accepted as the average requirement, then each animal would take approximately 4.7 pounds per month. The breeding population of the study area, calculated at 2.3 squirrels per acre (5 year average), would consume approximately 10.8 pounds per acre each month during the late winter and spring when most direct competition with livestock occurs. For the less accurately measured population over the Range, if the 1939-1940 calculation of 1.51 squirrels per acre in the breeding population is used, then 7.0 pounds per acre would be taken monthly.

For other times of year estimates of the food consumption are complicated by the presence of young in fluctuating numbers. The spring squirrel population is increased more than four-fold within a few weeks as the females give birth to litters. By the time the young are weaned, their numbers already have been much reduced, and by the time they have grown large enough to consume quantities comparable to those taken by adults, many more have been eliminated. The maximum rate of food consumption, occurring in early summer, may amount to nearly three times the monthly poundage consumed by the breeding population in early spring. But amounts consumed taper off rapidly through the summer and fall months, as death and retirement into dormancy reduce the active population.

The amount of vegetation eaten by squirrels, even if it could be determined with precision, would not be indicative of the full extent of damage to the forage crop, because there is further destruction by trampling, by cutting of stalks which are discarded or used only in part, and by stunting of the vege-

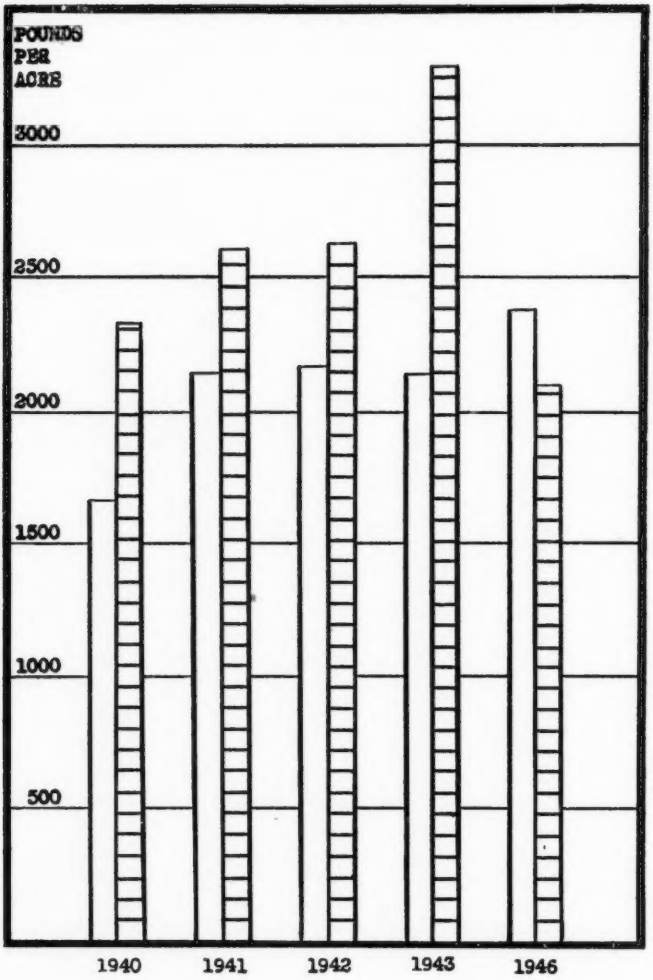

Figure 1.—Pounds per acre (air dry weight) of forage yield at height of growing season in a squirrel enclosure stocked at 12 squirrels per acre (left hand open column of each pair), and a control enclosure with no animal use (right hand, cross-hatched column of each pair). In 1946 the squirrels were removed, and the relatively greater yield of the squirrel enclosure that year indicates the amounts of forage destroyed by them other years.

tation which is eaten back during the early stages of growth. Data from the enclosures indicate that the use of vegetation by the squirrels reduces the yield by an amount considerably greater than the animals could have eaten, even allowing the maximum amount for each animal.

Effect on vegetation in enclosures.—Further data on the amount of vegetation destroyed by squirrels was provided by the half-acre enclosure where six were kept. At the height of the growing season in 1936, 1937, 1938, 1939 and 1940, visual estimates of the total density and the percentage of each forage species were made on 100 square-foot quadrats in the squirrel enclosure and the control. Hardly any significant trends in the differences between the two areas could be discerned. In the squirrel enclosure, however, broadleaf filaree, the favorite year-round food of the squirrels, was consistently less abundant than in the control. Its relative scarcity was compensated mainly by a greater abundance of soft-chess, little used by the squirrels except in the earliest stages of growth. Ground lupine, one of the less common forage species and a specially preferred squirrel food, comprised each year in the squirrel enclosure only a small fraction of its density in the control. These and other less well defined differences were not cumulative or progressive. Each year, both within the enclosures and outside, the amount and composition of the vegetation fluctuated widely under the influence of weather, and various factors other than squirrel use. With no animal use other than by the squirrels, utilization of the forage crop was extremely light, and competition between plant species was intensified. Each year at the beginning of the growing season after fall rains began, the accumulation of dead vegetation was raked up and removed from each enclosure to avoid the piling up of old growth choking out most of the broadleaf species and the transition to rank grasses which would have occurred otherwise. This artificial treatment further obscured the effect of the squirrels themselves.

In 1937, 1938, 1939, 1940, 1941 and 1942, the residue of dry forage on squirrel and control plots was measured at the end of the dry season (by weights of clippings from 100 square-foot random samples). In each of these years there was much less vegetation remaining on the squirrel enclosure than on the control, varying from 65.1 per cent to 83.3 per cent, and averaging 75.5 percent (figure 2).

In 1940, 1941, 1942 and 1943 the enclosures were further sampled by clipping of the green vegetation at the height of the growing season (100 square-foot quadrats) and weighing the air dry clippings (figure 1). The yield of the squirrel enclosure varied from 66.1 per cent to 82.3 per cent of that of the control, and averaged 75.4 per cent. In 1946 another sampling of yield was made with both enclosures virtually free from rodent use (a single surviving squirrel was trapped and removed from the squirrel enclosure in January). In 1946 the yield of the squirrel enclosure was 113.3* per cent of

* The approximate correctness of this percentage was borne out by a similar calibration sampling by the Experiment Station in 1947, when the control plot yielded 2054 pounds per acre and the squirrel plot, under protection, yielded 2386 pounds per acre, or 116.2 per cent.

the control. Using this 1946 figure as a standard of comparison, it appears that the squirrels destroyed on the average each year during the growing season an amount equivalent to 37.9 per cent of the yield produced by the control enclosure. The yield of the squirrel enclosure was reduced by an amount varying from 801 to 1629 pounds per acre (average 1058) in the four years that green clippings were made.

It is immediately apparent that these quantities greatly exceed the amounts

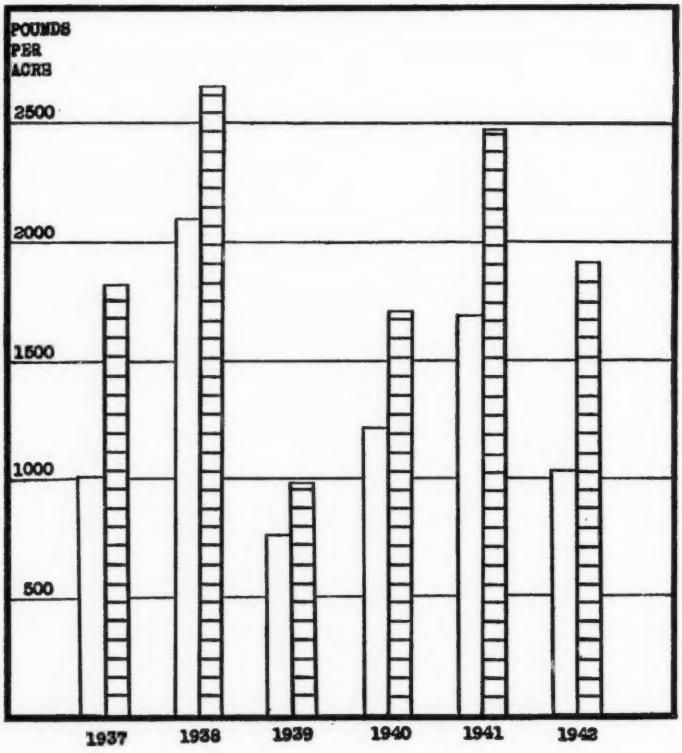

Figure 2.—Pounds per acre of dry forage remaining in September in squirrel enclosure (left hand, open column of each pair) and in control. Note reduced poundage in both enclosures as compared with Figure 1, the relatively greater difference, and the year-to-year fluctuations.

that could have been eaten by the squirrels. In the 210 days representing the average span of the growing season, twelve squirrels eating probably not more than 70 grams apiece daily of green stuff would consume a total of 389 pounds. At least seventy-five per cent of the weight is moisture. The air dry weight represented—97.5 pounds—is less than one-tenth of the average quantity apparently destroyed by squirrel activity in the enclosure. Much of this discrepancy must be due to the stunting effect that results from cropping of small plants in their early stages of growth. Cutting of plants which are not eaten, and trampling could account for further loss.

The enclosure data show the potential destructiveness of the squirrels, but do not show how much they destroy on the open range. In the enclosure, with a greater quantity of vegetation present, the amount cut and trampled per squirrel is probably greater, and destruction tends to be magnified. On the range, with stock and other animals competing for the vegetation, the destruction per squirrel is doubtless less. Maximum destruction in poundage per squirrel might be expected in those years when the forage crop is heaviest. The composition of the forage crop also would be a factor determining the amount destroyed.

The measurements of squirrel damage in the enclosure are subject to some margin of error from other causes. Mortality was fairly frequent and deaths were not always discovered immediately, so, at times, the area was understocked. Too frequent trapping in the plot to check the number of squirrels would have resulted in further disturbance and trampling of the vegetation. Being limited in their movements, the enclosed squirrels were less able to find succulence or free water than were those of the unconfined population. Apparently as a result of this deficiency, they always became emaciated in summer. One oak tree grew inside the enclosure, and use of the varying acorn crop partially diverted the squirrels from the forage crop, especially in summer and fall.

The conclusions indicated by the enclosure data are that squirrel use in the population density of 12 per acre does not harmfully alter the composition of the forage crop, which shows only light utilization; that the annual forage yield under this degree of use is decreased, apparently in the neighborhood of one thousand pounds per acre; and that the quantity actually eaten by the squirrels is much less than that otherwise eliminated by them.

Kinds of food eaten.—In their feeding ground squirrels take mainly the more nutritious kinds of plant food available. Many plant species are entirely ignored by them, and others are utilized only to the extent of one particular part or organ. In general, high content of crude protein and essential minerals, and comparatively low content of crude fiber and cellulose characterize most of the types of vegetation selected as food. Composition (in percentages of dry weights) of some of the favorite foods at different seasons are shown below. The figures are from those published by Gordon and Sampson (1939).

TABLE 5.—Composition of forage plants.

LEAF

Kind of plant	Month	Contents			
		Calcium	Phosphorus	Crude Protein	Fiber
Soft chess	February	.86	.49	22.50	24.60
Red brome	March	.57	.24	26.63	——
Broadleaf filaree	December	1.79	.40	26.70	10.94
Redstem filaree	January	2.02	.51	29.29	9.38
Yellow tarweed	June	1.39	.20	7.62	20.72
Ground lupine	March	1.57	.46	27.43	18.53
Popcorn flower	February	2.01	.76	28.20	12.60

SEED

Kind of plant	Month	Contents			
		Calcium	Phosphorus	Crude Protein	Fiber
Ripgut brome	June	.14	.34	10.68	6.14
Broadleaf filaree	August	1.34	1.54	29.99	18.15
Yellow tarweed	June	.31	.67	22.79	19.19
Layia	August	.67	.82	20.89	19.21
Popcorn flower	August	1.34	.84	30.93	——
Blue oak	November	.08	.11	5.01	6.31
Wedgeleaf ceanothus	June	.35	.31	22.43	——

The above figures, show that certain summer and fall foods, as acorns, and ripgut brome seeds, are deficient both in protein and in mineral content, as compared with the diet at other times of year. The behavior of squirrels feeding upon tarweed and acorns indicated clearly that these were foods low on their scale of preference, and were taken only in the absence of the foods which better supply nutrition and succulence at other seasons. Use of tarweed seeds stopped as soon as new green growth was available in the fall. Blue oak acorn meats were discarded in part, after nibbling, more often than they were eaten entire, and were often carried about in the cheek pouches for hours before being used at all. Even in the dry season, however, the diet is relatively high in essential food elements as compared with the forage crop as a whole. Summer composition of the common range plants is very low in protein. For instance, in September, soft chess contains: calcium .241 per cent; phosphorus .164 per cent; crude fiber 38.32 per cent; crude protein 3.76 per cent. In June broadleaf filaree contains: calcium 2.444 per cent; phosphorus .169 per cent; crude fiber 28.70 per cent; crude protein 3.36 per cent. In the dry season these two species are important, though nutritionally deficient, stock foods, but are not used at all by the squirrels. Most of the other common herbaceous species show similar trends in the high percentage of fiber and low percentage of protein after drying at the end of the growing season.

Leaves are an important food source, and 40 kinds were recorded used, principally in winter and early spring. Hardly any dry leaf material is taken, and tarweed is about the only kind used during the dry season. August is the only month of the year during which no use of foliage was observed. Foliage of herbs such as filaree and popcorn flower was used mostly in the rosette stage before the plants had produced heads.

Flowers of 34 kinds were utilized and they constitute a major food source, from January through September. During March, April and May the many kinds of flowers taken seem to include some of the most preferred foods, and may be an important cause of the rapid weight gain during late spring. Mature seeds were taken from 18 different kinds of plants, and seed material comprises most of the food from the height of the growing season until the fall rains set in. In late spring the varied diet includes many kinds of seeds whereas throughout late summer and fall a few species make up most of the food—principally acorn, tarweed, turkey mullein, and ripgut grass. Fruits, capsules, or berries, (consisting mainly of the fleshy encasing wall rather than the enclosed seed material) were eaten from 12 species. Stem material is a minor part of the diet, and was used from only 7 kinds of plants. It is taken mostly in early spring while still tender and succulent, and its use is mainly incidental at times when the squirrels are feeding on foliage of the same species. Occasionally during the dry season old stems of filaree or popcorn flower are nibbled, but do not make up an appreciable part of the food. At times small plants are dug or pulled out and eaten entire. Filaree and ground lupine are those that serve importantly in this way, but 11 kinds have been recorded used. Subterranean portions of plants were recorded eaten from only four kinds, not including certain fungi and toadstools which were seen used on several occasions but were not identified.

Seasonal changes in the parts of plants used as food are shown in the following table. It is seen that leaf and stem material make up most of the diet during the early stages of growth in winter and decrease abruptly in spring when many kinds of flowers and seeds, ripe but still succulent, are preferred. Leaf and stem material (tarweed) again increase in importance in the dry season, apparently as a source of succulence. Flowers are eaten in nine months of the year, but mainly in late spring and early summer. Seeds other than acorns are eaten through most of the year but make up highest percentages of the food in late spring. In the table, acorn is included in the "seed" column but also is shown separately.

TABLE 6.—Monthly percentages of plant parts in the ground squirrel diet.

	Leaf and Stem	*Flower*	*Seed*	
			Total	Acorn
January	97.3	1.8	.9	(.9)
February	80.0	1.2	18.8	(18.8)
March	45.5	1.0	53.5	(10.5)
April	17.4	8.5	74.1	(1.6)

TABLE 6.—(*Continued.*)

	Leaf and Stem	*Flower*	*Seed*	
			Total	Acorn
May	.8	9.2	90.0	—
June	17.1	12.1	70.8	(13.7)
July	27.5	20.7	51.8	(23.1)
August	3.9	7.9	88.2	(63.9)
September	—	6.0	94.0	(62.5)
October	.2	—	98.8	(62.7)
November	16.9	—	83.1	(83.1)
December	98.0	—	2.0	(2.0)

The following list summarizes the kinds of plants seen eaten, the months of the year during which each was used, and the part of each taken. For parts of plants the following abbreviations are used: L = leaf, F = flower, S = seed, Fr = fruit, St = stem, Pl = entire plant, R = root, B = bulb or corm. Months are indicated by number; 1 = January, etc. For the sake of brevity species are recorded in only a few instances in which the genera involved are among the more important foods, and the species differ importantly.

In many instances the season of squirrel use in any one year of a certain plant species and part is ordinarily shorter than indicated; the spread is due to its later or earlier development under the influence of varying weather, in the successive years of observation. A relatively few kinds of food make up the bulk of the diet, and most of the kinds of food here listed each made up only a fraction of one per cent of the total. For most kinds use was recorded regularly at about the same season each year, but some kinds were recorded in only one or two years. For example use of loosestrife was recorded many times during the early summer of 1938, but other years it was much scarcer and was not seen eaten.

The list is based on the 51,755 separate food items which squirrels were observed to eat in the course of monthly observations from April 1938 to January 1942. Samples of each kind were collected and weighed, and the monthly food composition by weight was calculated. In the list, those items marked with an asterisk made up more than one per cent of the monthly diet, while those marked with a double asterisk comprised more than ten per cent of the food for the month.

List of ground squirrel food plants on the San Joaquin Experimental Range, showing parts eaten and months of use.

Aesculus, Buckeye (L-9; F-6*; S-10*)

Amsinckia, Buckthorn weed (L-1, 2, 3, 4, 5)

Agoseris, Dandelion (L-3; F-4, 5*)

Arctostaphylos, Manzanita (F-1*, 2, 3; Fr.-4*, 6**, 7*)

Astragalus, Locoweed (L-2)

Avena, Oat (S-4, 5, 6)

Baeria, Goldfields (F-3, 4*)

Brodiaea, Blue-dicks (L-3, 4, 5; F-4, 5*; Fr-5; B-4)

Bromus mollis, Soft chess (L-1, 2*, 3, 4, 10, 11*, 12; S-5, 6)

Bromus rigidus, Ripgut brome L-5, 6, 10; S-5**, 6, 7, 8*, 9)

Bromus rubens, Red brome (L-1, 2, 3, 12)

Calandrinia, Red maids

(L and St-1*, 2*, 3*, 4, 5, 6, 11*, 12; F-3; Pl-1)

Ceanothus, Wedgeleaf ceanothus (Fr-6)

Centaurea, Star thistle (L-3*; S-6)

Cerastium, Mouse-ear chickweed (L-4)

Dodecatheon, Shooting star (L-3)

Echinocystis, Man-root (L-4)

Eremocarpus, Turkey mullein (F-7*, 8, 9; S-8, 9*)

Eriogonum, Eriogonum (L-7; F-6*, 7**, 8**, 9*; St-7, 8)

Erodium botrys, Broadleaf filaree (L-1**, 2**, 3**, 4**, 5, 6, 10, 11*, 12**; F-3*; Fr-3*, 4**, 5, 6; S-5**, 6**, 7**, 8, 9; St-3, 4, 5, 6; Pl-1, 2, 3, 11, 12; R-5, 7)

Erodium cicutarium, Red-stem filaree L-1, 2, 3, 4, 12; F-3; Fr-3, 4, 5; Pl-1, 2; R-1, 12)

Erysmium, Wall flower (L-2)

Eschscholtzia, California poppy (L and F-3, 4)

Festuca, Fescue (L-1, 2, 3, 11, 12*; Pl-12)

Gilia, Gilia (F-4,5)

Gnaphalium, Everlasting (F-6, 7)

Godetia, Godetia (F-5, 6; Pl-6)

Hemizonia virgata, Yellow tarweed (L and St-2*, 3*, 4, 6*, 7*; S-6, 7**, 8**, 9**, 10)

Hemizonia wrightii, Wright's tarweed (L-2*, 3; F-5, 6, 7; S-5, 6)

Hordeum, Wild barley (L-1, 2, 3, 11, 12; S-5, 6; Pl-3; R-5)

Hypochoeris, Rush (L-1, 4)

Juncus, Rush (L-3, 6; S-5)

Layia, Layia (F-4)

Lessingia, Lessingia (L and St and Pl-2)

Lotus americanus, Spanish clover (L-4, 5, 6, 7; Fr-1)

Lotus strigosus, Hairy lotus (L-2, 3; F-4; Fr-4, 5)

Lotus subpinnatus, Fine-leaf lotus (L-6)

Lupinus benthami, Lupine (F and Fr-4)

Lupinus bicolor, Ground lupine (L-2, 3**, 4*; Pl and St-3, 4; Fr-3, 4, 5)

Lupinus formosus, Lupine (L and F-4, 5*; Fr-5)

Lythrum, Loosestrife (L and S and Pl-6)

Madia, Tarweed (F-7*)

Mimulus, Snapdragon (F-4)

Navarettia, Navarettia (F-6, 7)

Nemophila, Baby blue-eyes (L-1, 2, 3)

Oenothera, Evening primrose (F-3)

Orthocarpus, Owl's clover (L and Fr-3)

Pectocarya, Pectocarya (F-3)

Phacelia, Phacelia (L-3, 4*; F-4)

Pinus, Digger pine (S-1, 2, 3, 8, 11)

Plagiobothrys, Popcorn flower (L-1*, 2*, 3*, 4, 10, 11*, 12*; S-3, 4*, 5; St-7)

Pterostegia, Pterostegia (L-3)

Quercus douglasii, Blue oak (S-2**, 3**, 4*, 6*, 7**, 8**, 9**, 10**, 11**)

Quercus wislizenii, Interior live-oak (S-1, 2**, 3*, 6**, 7**, 8**, 9**, 10**, 11**, 12*)

Rhamnus, Redberry (Fr-6*, 7)

Scrophularia, Figwort (F-4)

Silene, Windmill Pink (L-3; S-5, 6, 7)

Stellaria, Chickweed (L-2, 3)

Thysanocarpus, Fringe-pod (F-4)

Tillea, Tillea (Pl-2*)

Trifolium, Clover (L-3, 4*, 5; F-4*, 5*, 6; Pl-6)

Tropidocarpum, Tropidocarpum (L and F-2, 3)

All those plants species were eaten which usually comprised as much as one per cent by volume of the forage crop in years when the vegetation was measured. Common plant species make up nearly all of the food and availability is an important factor in determining what is taken. Some moderately common plants apparently are avoided. Listed below are 53 kinds not observed to be eaten by squirrels. Specific names are included only when there is present on the area some other species of the same genus which *is* utilized by the squirrels.

List of plants on San Joaquin Experimental Range not observed eaten by ground squirrels

Allocarya	*Eriodictyon*	*Plantago*
Amsinckia (intermedia)	*Eriophyllum*	*Poa*
Asclepias	*Eschscholtzia (californica)*	*Pogogyne*
Brickellia	*Euphorbia*	*Polypogon*
Briza	*Filago*	*Pellea*
Capsella	*Galium*	*Ranunculus*
Ceanothus (divaricatus)	*Gymnogramme*	*Rumex*
Cephalanthus	*Heliotropum*	*Salix*
Calycadenia	*Hugelia*	*Saxifraga*
Chorizanthe	*Limnanthus*	*Scutellaria*
Clarkia	*Linanthus*	*Sidalcea*
Collinsia	*Lithophragma*	*Solanum*
Cynodon	*Matricaria*	*Stachys*
Cyperus	*Mimetanthe*	*Stipa*
Daucus	*Micropus*	*Streptanthus*
Delphinium	*Molluga*	*Trichostema*
Eleocharis	*Nicotiana*	*Uropappus*
Erigeron		*Xanthium*

In addition to the plants of this list, there were 45 other uncommon or rare genera which were not seen used by the squirrels.

In summer and fall but little economic damage to the forage crop results from the actual feeding of squirrels since the acorns, tarweed foliage and seeds, eriogonum, turkey mullein seeds and staminate flowers, cast seeds of ripgut grass and cast seeds of filaree used then are not available or palatable to cattle. Squirrel damage to the forage crop in summer must be due largely to trampling.

In winter squirrels are using for food the same herbaceous green material grazed by cattle. Their feeding is then in direct competition with livestock except to the extent that they are still using acorns stored by them in the fall. As the growing season progresses, the squirrels become gradually more selective in their feeding and begin to take flower and seed material some of which is little used by stock. In general most of the damage to the forage is done during the period of green growth in late fall, winter, and early spring.

The amount of forage destroyed by a squirrel in the course of its daily feeding hence varies according to the season. The loss is greatest in spring at about the height of the growing season, when, occasionally, entire mature plants such as wild oats are cut in order to secure the relatively small portion desired as food. In hay fields such cutting of stalks may almost completely destroy the crop on the area where a squirrel forages. In utilizing filaree seeds not yet cast from the plants, the squirrels pluck the entire fruits the exteriors of which are discarded after removal of the relatively small seeds. In a sample of filaree fruits similar to those used by squirrels, the parts habitually discarded—receptacle, sepals, styles and carpel walls—comprised 79.1 per cent by weight.

As might be expected feeding is determined largely by availability of food species where the animal occurs. Though there is rapid change in food during the season, there are usually several kinds of plants at stages of development

at which they are acceptable as food at any one time, and of these the most readily obtainable will be taken in largest quantities. Composition of the plant community varies greatly on different pastures of the Range and also varies within small areas, so that no two squirrels living at different places have exactly the same amounts or kinds of food available. In watching the feeding of squirrels, the observer is constantly impressed with their selectivity, especially so in the later stages of plant growth, when they use only certain species and certain parts of the plants. Actually their foraging is directed at only a small percentage by bulk of the total forage crop at such times. Certain species such as windmill pink, ground lupine, and loosestrife, which make up only insignificant parts of the forage crop, are, at times, sought so persistently that they constitute important parts of the diet. They are least selective during the early stages of green growth, and at times seem to graze indiscriminately off the surface mat of vegetation.

The preponderance of two kinds of plants among the many comprising the diet is illustrated by the following table of their computed percentages by weight in the total food observed taken. It is shown that filaree makes up the bulk of the food throughout the winter and spring and gradually diminishes to an insignificant proportion at the end of the dry season; that acorn during the same period gradually increases from a small percentage in early spring to more than three-fourths of the total in fall. Grass is taken throughout most of the year but in relatively small quantities. Acorn and filaree combined outweigh all other foods except in June and July; in these months tarweed and eriogonum are of major importance.

TABLE 7.—Percentage by weights of filaree, acorn, and grass in ground squirrel diet.

	Filaree	*Acorn*	*Grass*	*Other*
January	90.2	.9	1.5	7.4
February	53.8	18.8	3.1	24.3
March	49.4	10.5	1.1	39.0
April	72.8	1.6	.1	25.5
May	70.6	—	14.2	15.2
June	33.8	13.7	.1	52.4
July	22.0	23.1	—	54.9
August	2.0	63.9	2.6	31.5
September	.7	62.5	1.0	35.8
October	—	62.7	.2	37.1
November	11.2	83.1	2.9	2.8
December	92.2	2.0	2.8	3.0

Filaree is the most important food source in this locality, and in one stage or another it is used throughout most of the year. Foliage is used from the time its growth starts in the fall until it dries out in late spring, entire plants are taken during the early rosette stage in the winter, flowers and fruits during the later stages of growth, and seeds both before and after they are cast, and to a diminishing extent throughout the summer. The establishment of this alien plant in the range of the California ground squirrel must have profoundly

affected the animal's ecology, and doubtless permits its existence in higher population densities than could otherwise find sustenance. Red-stem filaree apparently is preferred, but broadleaf, being more abundant on the Range, is more used there.

The plants are eaten entire mostly when the leaf expanse of the rosette is an inch or two in diameter. Heaviest utilization was observed at times in early winter when the soil was dry, following a rainless period. A squirrel would scratch away the dirt at the base and grasp the plant beneath the rosette with its incisors to uproot it. Occasionally the attenuate terminal portion of the root was discarded, but the fleshy basal portion was eaten with relish. At times when the soil was moist, squirrels feeding on young filaree plants snipped off separate leaves rather than uprooting entire plants. As the turgid petioles were cut, distinct snaps were audible to an observer within several yards, rendering it easy to count the leaves eaten. Small undeveloped leaves near the center of the rosette and large basal leaves lying against the ground usually are not taken. In filaree plants grown past the rosette stage, the leaves are used much less. The flowers and immature fruits are occasionally eaten, when the squirrels are foraging mainly for the leaves. Sometimes only the style or "stork's bill" portion of an immature fruit is cut off and eaten.

When the fruits have begun to mature they are no longer eaten entire, but are plucked, stripped of their seeds and discarded. For many weeks during

Figure 3.—Finishing root of a Filaree plant, rosette of leaves already eaten.

the spring filaree seeds continue to be a principal food source of the squirrel population, and in this period rapid gain in weight is made. The foraging squirrel reaches for each fruit with its forefeet, catches it between the incisors, and plucks it with a sudden sideways jerk. Then, holding the elongate "stork's bill" of the combined styles between the forepaws, and twirling it with a rapid rotary motion, it gouges out the seeds from beneath the sepals with its lower incisors.

In late spring when the forage crop has mainly dried out, squirrels occasionally take fleshy joints of filaree stems in which succulence still remains. Just after seed-casting, filaree seeds can be procured in quantity in certain places where heaps of the long coiled styles, with carpels still attached, accumulate. Gathering of these minute items is accomplished with great rapidity as the squirrel grasps the seeds one after another, between its incisors and snips off the dry styles, sometimes at the rate of several in a second. After a few weeks, the remaining seeds have become less accessible. The barbed carpels enclosing the seeds have bored into the ground, aided by the spring mechanism of the attached hygroscopic styles, and, as a result of trampling and wind, most of the brittle styles have been broken off. In getting the seeds, a squirrel employs its forepaws to advantage for manipulating the styles to guide the attached carpels to its mouth. On two occasions squirrels feeding entirely on cast filaree seeds which they were gathering from the ground were seen to pause and eat small quantities which they had pouched, but pouching of such minute seeds occurs only exceptionally. Soon after the beginning of fall rains in October, the germinating seeds of filaree are extensively used.

Use of acorns has been recorded for every month except May. In the latter part of June, with the forage crop already mostly dried and high temperatures often preventing extensive foraging expeditions in the open, the squirrels begin to climb through oak trees in search of the small green acorns, which are used in large numbers because of their minute size. Trees which are bearing heavily are discovered and returned to regularly, until the squirrels have largely shifted their activities to oaks, where they spend most of their time climbing or loafing in the shade. By the end of July a substantial portion of the acorn crop may have been used. Meanwhile the remaining acorns have been growing rapidly.

In climbing through the outer branches of trees to gather acorns, the squirrels clumsily knock off more than they themselves secure. Also, many acorns are intentionally dropped by them, some after having been hulled out and briefly nibbled. The abundance of acorns and their monotony as a steady diet cause the squirrels to leave more than they eat. The meats hulled out by them are made available to various other acorn eating wildlife species. Most of the acorn mast taken by Valley quail at this locality is that discarded by squirrels (Glading, Biswell and Smith, 1940:138). In August and September pouching of acorns is commonly observed as the squirrels gather heavy loads and carry them back to feeding places. Large and ripe acorns are nearly always carried to the ground before being eaten. When fallen acorns accumulate it

becomes profitable for the squirrels to forage beneath the trees. Ordinarily the supply of acorns is greatly in excess of the squirrels' immediate need. Often the meats are shelled out, nibbled, and then dropped or pouched. While loafing or foraging the squirrels are often carrying pouched acorns which may be nibbled from time to time.

In October when acorns are present in greatest abundance and have ripened, squirrel activity is to a large extent devoted to laying up caches. So far as observed, acorns are the only natural food regularly cached in this region. Caches are made mainly in the afternoon after the main feeding period for the day is over, and fallen acorns are used. In gathering them squirrels display unusually sustained activity, searching over the ground surface with short hurried movements, nosing though debris and rapidly pouching those found. When the small, elongate acorns of live-oak are gathered, a dozen or more often are carried in the cheek pouches, which are greatly distended by them. At close range a faint rattling is audible when the squirrel moves, as the pouched acorns shake together. Most frequently caches are made at distances of 100 feet or more from the places where acorns are gathered. Having filled its pouches to capacity, the squirrel suddenly ceases to search and usually following some beaten path runs from the foraging place to its caching area. There, moving slowly, it examines the ground minutely for a few seconds selecting a place for the cache. In a few seconds a pit, commonly about three inches in depth, is dug with rapid strokes of the forefeet, and the squirrel

Figure 4.—Caching pouched grain.

leans forward, with its head in the pit to eject part or all of its load of acorns by movements of its tongue and cheek muscles (figure 4). Then it rapidly scratches loose dirt back over the acorns and finishes the process by forward tamping movements with the soles of its forefeet (figure 5), leaving no discernible trace. Usually a pouch full of acorns serves to fill several caches. Often a squirrel abandons a pit when it is only partly dug, and searches for another site. No notice was taken by squirrels, conditioned to the presence of humans, of persons following closely and digging out each cache as the squirrel left it. The animal would dig unconcernedly a few yards away and deposit another cache.

That the caches are not separately remembered and returned to by a squirrel is suggested by the haphazard and hurried manner in which they are made, often after several false starts, and by the fact that the animal after completing a cache seemingly fails to take careful note of its location before moving on. In preparing to make a cache the squirrel may move several feet, sniffing and occasionally scratching at the ground immediately in front of it before finally digging the pit and depositing its load. It fills the pit and moves on with no more than a momentary pause and with no apparent attention to nearby landmarks which might aid in relocating the cache on some subsequent occasion. In any case a squirrel would scarcely be able to remember the separate locations of the several hundred caches made by it during the acorn season. In January 1940, after the fall crop of acorns had disappeared, a squirrel

Figure 5.—Covering over a cache.

was observed recovering acorns from caches in sandy soil near a creek bed. It was feeding in part on new green vegetation, but the stored acorns seemed to make up the greater part of its food. Much of its foraging time, several hours daily, was spent digging more or less aimlessly in the general area where caches had been made, but it was evident that the caches were not separately remembered. It seemed to be aided to some degree by scent when the acorn sought was near at hand.

In January 1939, weeks after the fall acorn crop had disappeared, an adult female was seen making numerous trips into her home burrow, emerging each time with pouches full of live-oak acorns, which were then stored in typical surface caches in the vicinity. Some of these acorns had sprouts several inches long which protruded from the squirrel's mouth as she carried them. The nearest live-oak was more than 100 yards distant from the home burrow of this squirrel, and beyond its usual foraging range. On several other occasions in winter and early spring squirrels were observed to emerge from their burrows with pouched acorns which had evidently been stored there in fall. Grinnell and Dixon (1918:629) cite several instances of finding food stores in burrows. Extensive excavation was not possible in the present study, but it is believed

Figure 6.—Eating leaves of Tarweed in July.

that such storing is not a common habit locally else it would have been seen oftener during the many hundred hours spent watching squirrels.

Yellow tarweed is one of the important food plants for squirrels in the region of the Experimental Range. During winter and early spring the tender new leaves are used along with the foliage of many other plant species but as the squirrels become more selective in their feeding, and take mostly flower and seed material, tarweed is hardly used. In June, after drying out of the main forage crop tarweed is one of the few succulent herbs remaining, and the squirrels again turn to it as an important food source (figure 6). At this time of year only the leaves and the more tender terminal portions of stems are taken; the coarse pithy stalks are not attacked. Plants which have been grazed back by cattle, and have stooled out with a dense growth of succulent leaves are favored. Since only a small percentage of the squirrel population lives within reach of watering places during the dry season, the succulence available in

Figure 7.—Eating seeds of Tarweed in September.

tarweed may be a vital factor in providing them with the necessary amount of moisture. Utilization continues through July and early August. Usually in August or September, as tarweed passes the height of its flowering season, the squirrels commence to utilize its seeds. For several weeks these seeds continue to be heavily used and, with acorns, comprise most of the squirrels' food. At this season daytime temperatures in the open still are apt to be uncomfortably high for the squirrels, so that much of their foraging is done in shade of trees and bushes. During morning and evening foraging periods when temperature is more moderate, they venture into the open to obtain the seeds, moving about rapidly, standing on their hind legs and reaching up for the slender fruiting branchlets with their forepaws and dragging the flowers down to their mouths (figure 7). Tarweed seeds may be preferred to acorns, as the latter are taken mainly when the tarweed is unavailable due to excessive sunshine temperatures.

The less common Wright's tarweed is utilized to a limited extent, in situa-

Figure 8.—Eating nutlets of Popcorn Flower.

tions where it occurs, during early spring. In May the seeds of this early-flowering species are occasionally eaten by squirrels.

Grass amounted to only a small fraction of the diet (14.2 per cent in May; 3 per cent or less in other months). In late fall and early winter all the common annual species were grazed along with other new growth, but broad-leaved herbs were taken in much greater quantity, either because they were more easily secured, or because they were actually preferred. No use in any form of the several perennial grasses was recorded.

Grass seeds are taken mostly in late spring when they are maturing and "in the milk" but are still attached to the plants. Heads of ripgut brome are easily reached from the ground, but stalks of tall wild oat are more apt to be cut at the base. On several occasions squirrels seen to cut the long stalks left most of the head unused, possibly because it could not be sampled beforehand to determine whether it had attained the proper stage of ripeness. Only those grass species with relatively large seeds are used to any important extent. Red brome seeds, similar to those of ripgut except for size, have never been observed used by the squirrels, nor have the small seeds of the abundant fescue. Seeds of soft chess and of Australian chess are rarely sampled though they are common and readily available, indicating that they must be low on the scale of preference as squirrel foods.

Popcorn flower is much used in winter and spring. Under primitive conditions before filaree became established it may have been the most important winter food. In the early rosette stage, the plants like those of filaree, are sometimes dug out and eaten entire. The foliage is less used after the onset of rapid spring growth. For a short time when the plants have matured, and before the seeds are cast, squirrels take the ripe nutlets by drawing the stems crosswise through their mouths with rapid movements of the forepaws removing each nutlet with the tongue and lower incisors. Seeds of phacelia and buckthorn weed are stripped from the stems in much the same manner, but are taken sparingly, and their hairy stems may be a deterrent.

During winter and early spring Red maids is avidly sought perhaps because of its tender and succulent quality. Often a squirrel will spend many minutes on an area of a few square inches feeding greedily from the dense mat formed by this plant. Flowers are preferred to the foliage. In May the crop has largely dried out and utilization is discontinued.

For a brief interval during spring, flowers of birds-eye gilia are much used but apparently the foliage and stems are distasteful. Gilia never makes up more than a small percentage of the composition but these flowers are conspicuously colored and of fairly uniform height, rendering it easy for a squirrel to gather it in quantity, catching the stems and directing the flowers to its mouth with quick movements of its forepaws.

Of the many kinds of food eaten only a few, the larger seeds, berries and fruits, are pouched. No pouching of flower, leaf or stem material has been observed, for these are eaten on the spot as they are gathered. Most kinds of seeds used are likewise eaten where they are found. Pouching shortens periods of active foraging by eliminating the time required for actual eating of the

food in an exposed situation away from shelter or above ground in trees or bushes where footing is precarious and there is danger of being caught helpless. Ordinarily it serves as a means of transporting food from such foraging places to nearby feeding places where it can be eaten in relative safety and comfort. At times when the sunshine temperature is near the maximum that can be endured by the squirrels, brief periods of hurried foraging alternate with longer intervals in which the squirrel retires to a shaded spot to lounge and eat at leisure (figure 9). The small seeds of Windmill Pink constitute an important food source in late spring, when sunshine temperatures usually are uncomfortably high in the exposed places where the plant grows. At the same season seed capsules of Godetia are similarly pouched in quantity and carried to feeding places by the squirrels. Ripe fruits of the shrub Wedgeleaf Ceanothus, where they are available, are moderately used by squirrels, and usually are pouched and carried to the ground before being eaten (figure 10).

Predatory habits.—Much has been written regarding the occasional meat-eating habits of various sciurids. Like most others the California ground squirrel sometimes takes animal food. Many instances of egg eating have been recorded on the Range. On one occasion a clutch of gopher snake eggs was found littered over a squirrel burrow mound, and the shells were broken open with their contents removed. Most of the bird nests involved were those of quail (Glading, 1938). On one occasion a squirrel was seen to dig out a quail egg from sand in the creek bed where evidently it had been cached. Bird eggs are often carried back to burrows to be eaten. Several instances of predation on nests of killdeer and mourning doves likewise have been recorded. Some of the dove nests destroyed were in low trees, others were on the ground. On one occasion a pair of brown towhees was seen fluttering at a squirrel and driving it along a horizontal live-oak limb toward the trunk of the tree. Investigation

Figure 9.—Eating seeds from pouched capsules of Windmill Pink, in shade of manzanita bush.

disclosed that the towhees' nest containing four young birds was situated in the outer twigs of the limb. No actual instances of squirrel predation on live birds have been observed. Foraging squirrels have been seen to make sudden dashes or lunges at mourning doves on the ground nearby. The doves invariably escaped untouched. Possibly such squirrels were merely driving away potential competitors. Small birds attracted to the traps by the bait—crowned sparrows, juncos, and occasional lark sparrows—are sometimes caught along with a squirrel. In such instances the bird is usually found dead and partly eaten. Once a squirrel was caught in a large wire funnel trap with several white-crowned sparrows. As it dashed about eluding attempts to remove it, one of the sparrows fluttered within reach; instantly the squirrel seized the bird in its forepaws and killed it, with a quick bite, then dropped it. On August 5, 1938, an adult squirrel foraging through a rock outcrop where a pair of adult California quail with their brood of small young were resting caused the hen quail to give high alarm notes, and instantly the young scattered and hid. The cock quail also gave alarm notes and threateningly strutted toward the squirrel, which cowered back under twigs of a protecting oak limb and sat there motionless. The two adult quail ran about fifty feet away to a thick live-oak where they hesitated and walked about nervously, uttering clucking sounds. The squirrel soon resumed foraging, nosing about over the ground still within the area where the young quail were hiding, but either it

Figure 10.—Climbing for ripe fruits of Wedgeleaf Ceanothus.

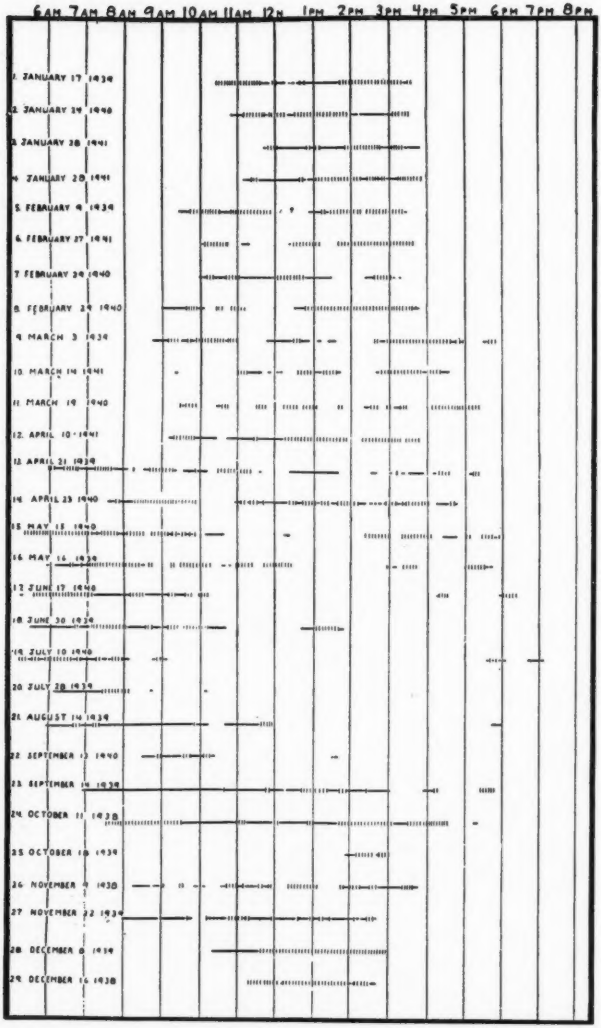

Figure 11.—Diagram showing time spent above ground by individual squirrels on 29 full days of observation. Vertically parallel lines represent active foraging, horizontal lines represent time spent otherwise (as in loafing, caching, or exploring). Note short active days with concentrated mid-day foraging in winter, and relatively longer days with early morning foraging during summer.

did not find any, or it was not interested in them. After five minutes the young quail began to emerge from hiding, gave high peeping rallying notes, and several ran together into a compact group. The squirrel was only a few feet away, within sight and hearing of the unprotected brood, but it paid no attention to them, and moved away to another rock outcrop. After a few seconds the cock quail ran down toward the brood, uttering warning notes which hushed their calls to a subdued peeping. This incident shows that the squirrels do not invariably prey upon birds when opportunities arise.

Grasshoppers seem to comprise the most often used source of animal food taken by the squirrels. Foraging squirrels have been seen to dash after flying grasshoppers flushed at their approach. In most observed cases the grasshopper flew too far for the squirrel to follow, or lit where it could not be found. In open situations such as paved roads, the squirrels' pursuit is more apt to be successful. One will make a series of quick runs and sharp turns persistently following a flying insect, which is finally pounced upon as it lands. On summer days when the temperature is not too high squirrels are commonly seen foraging for grasshoppers in the road and eating in quantity those crushed by passing automobiles.

Squirrels have been seen carrying or eating young cottontails which they had evidently taken from the nests. Once an adult cottontail was seen chasing a squirrel around the side of a bush, possibly in an attempt to defend its nest.

A squirrel was seen carrying a large adult pocket gopher which was still warm, limp, and bleeding, and was found to have a puncture through the back of the skull, evidently made by the squirrel's incisors. This gopher may have been taken by surprise away from its burrow. Another time a squirrel was seen eating a young gopher. On other occasions squirrels have been seen to display only mild interest in gophers digging or emerging to feed in the vicinity, with no special attempt to stalk or catch them. Squirrels have also been seen carrying or eating remains of kangaroo rats, which may possibly have been caught in the burrows, or may have been found dead.

Squirrels are not averse to feeding upon members of their own species when opportunities arise, and individuals which die from disease or accident near burrows are apt to be partly devoured by others. The carcasses are handled in characteristic fashion; the side of the cranium is gnawed away and the brains are eaten out. The skin is torn back and the flesh gnawed away from the limb bones. One afternoon a few hours after poison had been distributed over a pasture, several dead squirrels were found near their burrows and one had the side of its face and an eye eaten away. Dissection of another squirrel found a few feet away disclosed the missing parts in its stomach. Squirrels run over on roads by passing automobiles are often fed upon by others.

These observations clearly indicate a tendency to seek meat or other animal food occasionally, and such food may be an essential part of the diet. Yet animal food, by bulk, must comprise an extremely small proportion of the diet. During the periods of intensive observations on feeding squirrels, the few small animal items consumed never made up appreciable percentages of the daily food.

BEHAVIOR

Foraging habits.—Detailed knowledge of the behavior, and the daily schedule of activity of squirrels is of practical value in the application of control measures. The time of activity during the day varies greatly according to temperature and other conditions. On mid-winter days dry and warm enough to favor squirrel activity, the animals are to be seen above ground, mostly between the hours of 10 or 11 a.m. and 4 p.m., and mainly within the period 11 a.m. to 3 p.m., (figure 11). In contrast, during the hotter part of the summer, hours of most pronounced activity are between 5 and 9 a.m. with another active period in late afternoon between 4 p.m. and dusk. During the mid-day hours when heat is intense, few are to be seen above ground and these limit their activity to shady spots, seldom venturing into the open. On cloudy or unseasonably cool days in late spring or summer, the squirrels are freed from the limitations imposed on them by intense heat, and are conspicuously

Figure 12.—Standing at attention in response to alarm chirp of another squirrel.

active during the mid-day hours. In winter there is some activity nearly every day unless rain is continuous, but wind, cold fog, and rain limit activity and cause foraging periods to be short and hurried. On a warm clear winter day following several cold and stormy ones, squirrel activity is at a peak, each animal foraging ravenously after the period of fasting.

During the course of normal foraging a squirrel grazes intently for usually only five or ten seconds, then pauses and looks about keenly for an instant, as it masticates the food secured. At intervals of a few minutes there are usually longer pauses during which the squirrel sits at attention and looks about for any sign of possible danger. Foraging squirrels are alert to the warning chirps of others, even though these may be hundreds of yards away. Upon hearing a chirp, the one foraging may sit up at attention (figure 12) or may hurry back to a more sheltered spot, or mount a rock or stump to obtain a better view.

In winter much of the feeding is done within the area of the burrow mounds where the squirrels live. New growth of herbaceous species acceptable as food is abundant almost everywhere, and feeding is limited more by the weather than by the actual supply of food. At this season squirrels are apt to emerge from their burrows about mid-morning and spend an hour or two sitting on boulders with hair fluffed out, sunning themselves and waiting for dew to dry off the vegetation before beginning to forage around noon. Fog closing in often sends them back underground for the day.

In making more extended foraging expeditions, a squirrel often heads for some outlying escape burrow which will serve as a refuge in any emergency, or it may visit a neighboring occupied burrow system. After satisfying its appetite, it may spend hours loafing in the vicinity, exploring the holes, or digging to enlarge them. At any sudden alarm, the natural tendency of a squirrel is to bolt for its home burrow. Sometimes one taken by surprise dashes straight toward the observer from a distance of 100 feet or more in order to reach its burrow. Or it may duck into any burrow which happens to be convenient for temporary refuge. Often, one which has resorted to such an emergency refuge reappears after a moment, for a homeward dash, but may duck back or into another convenient refuge with startled chirps, if it finds danger unexpectedly near. After the spring period of rapid forage growth, squirrels tend to extend their activities in correlation with their increasing selectivity of foods. Vegetation has become high enough to impede their movements, but it also affords effective concealment. Individuals taken by surprise often crouch motionless, or "freeze," and escape notice until at a favorable moment they run for their burrows.

After the beginning of the dry season, the vicinity of the burrow mounds no longer provides preferred foods and the animals habitually travel back and forth from them, visiting swales for remaining succulence, and trees and bushes for their acorns and berries, or merely for shade. Well beaten runways through the vegetation soon appear indicating the routes of travel.

Most intensive foraging periods are on short winter days, when a squirrel may feed for two or three hours with only brief pauses. As days become

warmer and longer in spring, periods of foraging become longer and more interrupted. Short expeditions into the open, or climbing above ground in trees and bushes may alternate with much longer periods of basking, loafing, dust bathing and occasional nibbling of pouched material. In hot summer weather, oak trees bcome the favorite resort of the squirrels, both as a source of food, and as protective shade. Burrows situated in exposed locations may be deserted, as the animals take over old ones beneath the trees, or dig new ones there. Foraging becomes mainly arboreal, and a squirrel may spend hours daily climbing through the trees. A small percentage of the squirrels even transfer their habitations to the trees and make straw nests in hollow trunks or limbs. These squirrels are clumsy climbers. When proceeding among the smaller branches and twigs, they may sprawl in ungainly fashion, with one or two legs hanging unable to find a foothold. Even when ascending or descending a sloping trunk, they usually move slowly with none of the grace of a tree squirrel. But on a few occasions individuals have shown agility and surefootedness in crossing on small twigs and branchlets from one tree to another along an apparently familiar course.

Individuality.—While reactions to certain situations and stimuli appear stereotyped, the existence of individual variation in temperament was one of the most striking traits of the squirrel population studied. This was impressively illustrated by the varying responses of different squirrels to the presence of humans. After nearly four years of baiting, live-trapping, and handling of those on the 80 acres where this study was concentrated, the population there was not conspicuously either tamer or wilder than squirrels on remote parts of the Range subject to little or no disturbances from humans. On any one area all degrees of wildness could be observed in different individual squirrels. Many were so wild that they would duck for shelter upon sighting a person 100 yards or more away, and would remain underground for a long time. Others were so tame that, even at a first encounter, they would permit a person to approach within 20 or 30 feet, and would continue to feed unconcernedly. The bulk of the population was somewhat intermediate with respect to degree of wildness and few would knowingly allow a person to approach within 100 feet, except perhaps when sitting alertly at a burrow entrance ready to duck underground.

Several unusually tame individuals were frequently followed and observed for the purpose of obtaining data on their feeding, and other habits. Such squirrels gradually become conditioned to the presence of humans, and would permit a person to come within three feet without displaying any uneasiness. All such animals appeared to be in good condition and, in so far as could be determined, were normal in every respect other than in their reactions to humans. Of nine such animals which were extensively observed over periods of months, seven were females and only two were males. One male and one female were apparently young of the year though of nearly adult size when discovered, the other seven were all old adults. Some of these tame squirrels were known for as much as two years, and their survival expectancy seemed fully as good as that of wilder ones. They were just as wary of traps as others,

and likewise seemed exceedingly watchful for their natural enemies. In each, as it was observed at close range, the constant alertness to detect snakes and other ground lurking enemies was impressive. In moving through thick vegetation, or around rocks or brush where its view was obstructed, such a squirrel was observed to proceed with the greatest caution. It would advance tensely, examining the ground around it carefully at each step, and often flinching nervously at the snapping of a stem or straw. Especial caution was displayed while going into a burrow entrance. In pausing to peer ahead, straining forward, the squirrel would flick its tail from side to side jerkily, in the same manner as one actually watching a snake. This behavior was most noticeable in warm weather when snakes were apt to be encountered.

In less tame squirrels, attempts to detect and avoid snakes could not be so well seen but may have been equally well developed. Those frightened to their burrows usually slowed down to a walk and entered cautiously if not too closely pressed. Others seen foraging in the distance moved about with the same tense, stalking gait.

Usually, tame squirrels seemed to ignore the presence of an observer but their behavior may have been somewhat influenced by his presence. After moving behind a bush or boulder obstructing its view, a squirrel sometimes would manuever around to its edge and peer out as if to assure itself that it was not being stalked. One too closely approached would suddenly become tense ready to dash for safety, but if the observer then waited quietly for a few seconds, it would either resume foraging as before on the spot, or bound away a few inches. Occasionally one closely approached while intent upon its foraging would suddenly notice the nearness of the observer and would sit up and eye him sharply for a few seconds, then turn away apparently satisfied as to his innocuousness. At times one displayed more active interest, and would run toward a person jerkily, a few steps at a time, until almost at his feet, then, sniffing, would look intently up at him. Traps, or other strange inanimate objects sometimes evoked the same reaction.

Social behavior.—Though ground squirrels live in close association, the general demeanor of one squirrel toward another is usually either indifference or intolerance. Individuals may happen to forage or rest within a few inches of each other with neither showing any interest in the other. Probably in these instances each has become accustomed to the other through long association, and one is most apt to be aggressive toward those with which it is not well acquainted. One venturing beyond its usual foraging range proceeds with caution and alertness, and is usually ready to retreat when threatened by another.

Often when two squirrels happen to be near together, one suddenly runs up to the other and noses it. The two animals may meet facing each other and touch noses, or nose each other vigorously about the mouths and cheeks. The action usually lasts only a second or two but may be quickly repeated. Linsdale (1946) records numerous instances of such behavior under differing circumstances which seem to indicate that age or sex are not determining factors.

Rather this behavior seems to be a stereotyped "meeting reaction" by which an individual asserts itself socially toward another and perhaps tests its reactions or its identity. Often such a meeting ends in a show of hostility. The approached squirrel may nip at the other but usually turns away and stands with tail arched as the other makes advances. If the nosing continues, the approached squirrel often gives its tail a violent flick, repulsing the other, and bounds away a few feet. This reaction—turning away and standing tense—seems to be an act of appeasement which discourages hostilities on the part of the one approaching. If the approached squirrel is inclined to resist, it faces and nips at the other with ears laid back and tail fluffed out. If neither is inclined to yield ground, they close in with slow, cat-like movements, and crowd each other, pushing with their inward-turned hindquarters. Occasionally one springs several inches off the ground. Most often such fights last only a few seconds and but little damage is done. Sometimes the fights are sufficiently violent and prolonged so that the combatants suffer serious injury. They may interlock and roll on the ground biting each other. Growls and high squeals are given during the fighting. Occasionally individuals are seen which have deep wounds, and sometimes these become seriously infected. Death may result in some cases, but probably squirrels are seldom or never killed outright in fights.

No evidence of territorialism in the usual sense was found in the course of the present study. Evans and Holdenreid (1943:258) attempt to establish from their obseravtions "that adult males maintained individual territories, which they defended against invasion by other males. . . ." In the present study it was often observed that five or more males occupied the same burrow system during the breeding season, while adjacent areas were unoccupied. The fighting which occurs constantly, cannot be considered truly territorial, but results from the naturally hostile tendency of each squirrel toward others, the aggressiveness associated with sexual behavior, and defense of food or feeding spot from use by others.

In instances where several adult males lived in close proximity, fights and pursuits were frequent, but there was no evident intent to exclude a rival from any definite territory. At times two such animals might forage for long periods within a few yards of each other, and of their burrows, with no show of hostility, or they might merely stalk around each other menacingly when they happened to meet. In the half acre enclosure where six male squirrels were kept, there was some indication of a scale of dominance and of subordination. Certain smaller animals seemed to be pursued and attacked much more frequently than the others.

Though fights are most frequent and conspicuous during the late winter and spring breeding season, they may occur at any time of year. A summer encounter between two large squirrels, probably males, was observed August 17, 1938, when snarling sounds attracted the observer's attention to one pursuing another over a boulder. It overtook the pursued one with a flying tackle, and they clinched and rolled about on the ground biting each other, their tails thrashing. One broke away and ran slowly and heavily for a few yards, then

paused. When it started again, the other pursued and overtook it, and a second time they interlocked rolling about on the ground. After several such clinches and breaks, the pursuing squirrel ran back in the direction from which it had come. The pursued stopped in a hunched position with its head resting on the ground, apparently injured in the fight.

In squirrels observed at close range, a habit commonly noticed was rubbing of the back against various objects such as bases or low branches of shrubs, and rocks of convenient height. The actions of such a squirrel resembled those of a friendly cat being stroked; it would rear up and turn sideways to press the object across its shoulders. The back rubbing was preceded and followed by a good deal of sniffing at the spot selected. This was a prominent phase of behavior in adult males loafing in the vicinity of their home burrows, and was even more noticeable in those exploring or visiting nearby burrow systems. It was interpreted as the leaving of scent, to advertise presence in, and occupancy of, a vicinity to other squirrels.

Since the above paragraph was written, Linsdale (1946:108-114) has described in detail the dorsal skin glands involved in the behavior just recorded. A glandular area of skin just behind the shoulders bears about 30 enlarged and modified sudoriparous glands which produce a musky scent. His accompanying table indicates that these glands are generally more numerous and better developed in males than in females. He mentions instances of animals rubbing the glandular area in loose earth, on a twig and the edge of a board, and states that sometimes a squirrel noses the side of another "as if to identify it." Also, he states: "The position of the glands indicates a possible use to discourage capture by a carnivore." This latter use seems improbable. Ground squirrels locally are a favorite prey species of all those bird, mammal and reptile predators large enough to obtain them. In numerous squirrel remains found left by various predators after making a meal, no tendency to avoid the glandular area in question was ever observed. Therefore, it appears most likely that a purely social function is subserved by the scent produced.

Late in September 1938, several days were spent in observation from a blind at a watering place which had become a focal point of squirrel activity. Many of the animals using it had been marked with colored celluloid ear disks for individual identification. Several were permanently resident in the area, others came distances of 100 to 200 yards beyond their usual foraging range to obtain water. The spot had been baited with grain and squirrels had formed the habit of loitering in the vicinity after drinking. Because of this unusual concentration, of more than thirty squirrels, quarreling was frequent. It was noticed that individuals which habitually frequented the area were most aggressive, while those which came from longer distances were relatively timid, and yielded ground readily. Age, size, and sex were less important than familiarity with surroundings in determining dominance. Most severe fights were between individuals which seemed familiar with the area. At this place half-grown young squirrels were observed to behave aggressively toward much larger ones, and an old adult female long resident in this vicinity was the most frequent

aggressor. Some fights had no apparent cause other than the crowding of the animals in close proximity. But in many instances it was evident that the attacking squirrel was driving the other from the bait, even when the bait was in a set trap which the defending squirrel was too cautious to enter.

Voice.—The familiar chirp of the ground squirrel varies significantly in pitch, loudness, and inflection according to the occasion. An individual animal uses its voice infrequently and only under unusual disturbance. One may pursue its routine activities for days at a time without making any vocal sound.

Perhaps the primary function of the voice is to warn other individuals in the community of an imminent danger. A distinctive type of chirp is that given in response to the sight of a hawk or other large bird flying in the vicinity. This consists of a single short syllable of unusual loudness and carrying quality;—"*cheesk*," or "*chisk*"—usually given as the animal bolts for shelter. Sometimes, two such notes are uttered in rapid succession. Other squirrels within hearing instantly come to attention or run for shelter, and each, in turn, repeats the alarm as it sights the object of potential danger. From these chirps, the course of a hawk may be traced along a canyon wall or over rolling hills as individual squirrels, already put on guard by others, sound the alarm, each as the bird comes within its range of vision. The red-tailed hawk is the most common source of danger evoking this type of alarm note. Hawks soaring high overhead seem not to be noticed by the squirrels as only those flying low excite alarm. Hawks perched in trees even at a fairly close range seem not to be noticed by squirrels until they fly; then instantly alarms are sounded. Horned owls are as much feared as hawks. Low-flying vultures apparently are not distinguished from large hawks and elicit the same response. On one occasion a squirrel was seen sitting near its burrow entrance alertly watching a vulture as the latter stood tearing at a dead squirrel only about 30 feet away. The squirrel's lack of fear in this instance evidently was due to the fact that the vulture was not in flight. Cooper hawks seem to be as much feared as the larger kinds. Sharp-shinned hawks have on several occasions been noted to cause squirrels to give alarm chirps but other times they have been seen to pass near without being noticed by squirrels, and they are apparently about the minimum size of birds recognized as potential enemies. California herons in several observed instances caused squirrels to give these alarm chirps. Often squirrels released from live-traps and running for shelter at close range give a single-syllabled chirp similar to the hawk warning but of more suppressed and less penetrating quality. A trapped squirrel when first approached gives a low, subdued note "*chisk!*", peculiar in its rising inflection and exclamatory quality.

A type of chirp usually distinctive is that given in response to sight of a snake. Upon seeing one, a squirrel edges up to it (figures 13 and 22) often coming within a foot or so, but always, in observed instances, keeping beyond its striking range. Straining forward tensely and sniffing, with its hind feet firmly planted, far back, and prepared to bound away, the squirrel examines the snake, and at short intervals, flicks its tail violently from side to side. It may back or sidle away, move around to another angle, and again face the snake to continue its watching at a new stance. Sometimes the whole perform-

once is carried out in silence but in most observed instances, peculiar chirps were given, "*cheet'-ik-irr-irr-irr*" distinctive in the low, vibrating quality, and the series of suppressed notes following the loud initial sharp note. These succeeding notes blend into each other producing a trilling or rolling sound which fades gradually toward its end. The sound has less carrying quality than some other chirps, as for example, the hawk warning, but nevertheless can be heard for considerable distances. On one occasion an observer located a squirrel and nearby snake, after recognizing the chirps and following up the sound from a distance of 700 yards. At a distance the trilling terminal notes usually are not audible, and the sharp initial chirp is not readily distinguishable as that of a snake warning. The most effective method of finding rattlesnakes on the Range was by listening for this "snake warning." Several field workers became familiar with the significance of this chirp and over a three year period dozens of rattlers were located by means of it. Considerable variation in the sound was noted from time to time. On some occasions when the chirp was not altogether typical, and lacked the distinctively prolonged terminal trill, investigation nevertheless disclosed that snakes were the cause of disturbance. But when the typical trilling chirps were heard, investigation nearly always yielded a snake, or at least fresh tracks in the vicinity showed that one had been there and had reached shelter before the observer arrived. One observer thought he was able to correlate variations of this chirp with the distance of the squirrel from the snake, the most typical, trilling chirps being given at close range, while sharper chirps lacking the trill and uttered at shorter intervals were given by squirrels watching a snake from a distance of several yards or more. The chirping and tail waving of squirrels which have located a snake serve to attract attention of others in the vicinity. Investigation of the characteristic chirp frequently has led an observer to a group of squirrels, as many as six, all gathered within an area of a few square yards and watching intently. Usually in such instances only one squirrel probably the original discoverer is chirping, though several may be flicking their tails. The warning value of the squirrel behavior is evident in such cases. Other squirrels foraging in the vicinity are informed of the presence and approximate location of the snake, and are often saved from coming suddenly upon it unawares and being struck. In nearly all recorded cases of "snake warning" the rattlesnake was the kind involved, it being by far the most abundant snake on the Experimental Range. However, in several instances, a gopher snake was found to be the source of disturbance; once a squirrel was found to be giving the "snake warning" as it watched a large garter snake, and another time one was found to have its attention focused upon a four-foot long California racer. In one exceptional instance when a typical "snake warning" chirp was investigated it was found that eight or ten squirrels were near the source of the disturbance perched on rocks and on branches of a live-oak all within 25 feet and watching intently, a centrally situated object. They did not disperse until the observers had come within a few yards. The squirrel which was chirping was five feet above the ground in a rock crevice, looking down upon a horned owl, which was sitting on the ground directly below it, and holding in its claws a freshly killed pocket gopher.

A chirp several times heard given by squirrels when a dog or coyote came into the vicinity, and frequently on other occasions in response to disturbance by humans, often consists of three syllables—*"chwee-chu-chuk!"* The first syllable is loud and sharp with the carrying quality of the "hawk warning." The second syllable is suppressed and the terminal syllable is loud and emphatic, with an exclamatory quality. The low middle syllable may be entirely omitted —*"chwee-chuk!"*—or it may be double—*"chwee-chu-chu-chuk!"* This chirp typically is given only once at an alarm, immediately after the source of danger is sighted and usually while the squirrel is sitting at attention; following it a series of less sharp chirps of one or two syllables may be given at intervals of a few seconds. These sharp chirps serve to forewarn other squirrels of the approach of a prowling predator while it is still distant.

A similar chirp is given on occasions of comparatively mild alarm such as when suddenly sighting in the middle distance a person or large animal which might or might not be a source of danger to the squirrel. This chirp might be written as *"cheesk'-isk-isk-isk-isk"*—with the first note loud and sharp and the following series of notes rapidly uttered varying in number blending into each other and becoming successively fainter. The terminal notes of this call are produced so rapidly that it is difficult to count them. The expulsion of air from the lungs by which each chirp is produced is accompanied by violent contractions of the diaphragm and muscles of the thorax and throat. Often the tail is given a quick flick as the initial sharp note of a chirp is sounded.

Mother squirrels warning their young of approach of a person or some other potential but comparatively mild danger have been heard to give a low melodious note—*"chwërt"*—uttered at intervals of two or three seconds over periods of minutes. It expresses uneasiness and distrust rather than an actual alarm. Litters of young playing around burrow entrances usually come to

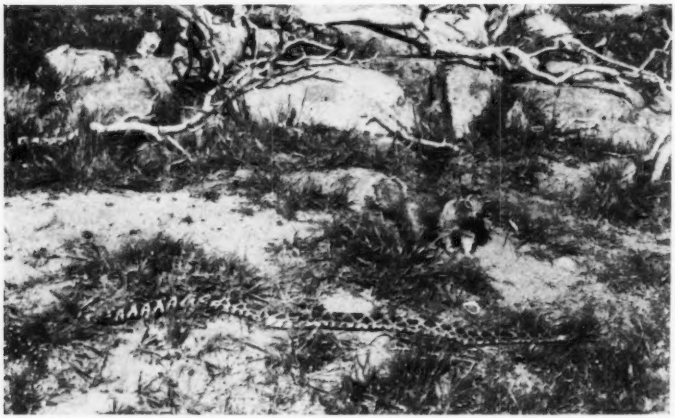

Figure 13.—Nervously watching a rattlesnake near burrows.

attention at the sound but do not retreat underground unless there is some further indication of danger. Squirrels which have uttered the alarm note described in the preceding paragraphs at sight of a predator have been heard to give series of these notes during the period of recovery before foraging was resumed.

Severity and kind of alarm rather than any stereotyped reaction to a specific predator as such, are the factors which determine the types of chirps given. Thus, the short, sharp "hawk warning" is generally given while the squirrel is frantically sprinting to its burrow. The "predator warning" is usually given as the squirrel sits in comparative safety within easy reach of some shelter, and utters the multiple notes of this chirp, with their distinctly scolding quality. The "snake warning" likewise is a scolding chirp uttered by an animal in no immediate danger, but keyed to a state of high nervous tension in the presence of its dreaded natural enemy. Foraging squirrels, under observation at the instant that snake warnings were given by individuals distant but within hearing, usually reacted by sitting at attention and looking about alert-

Figure 14.—On look-out in dead brush.

ly. If these squirrels had recognized the true significance of the warning chirps, they might have been expected to ignore the sound, since the discovery of rattlesnakes beyond the limits of their own small foraging areas would have no immediate importance to them.

All of the sounds so far described are modifications of the same basic chirp, but under unusual stress several other kinds of sounds are also produced. One of these is a low growl or snarl which principally seems to express defiance. It is given by squirrels caught in steel traps. Occasional individuals caught in box traps also growl with accompanying aggressive behavior; they may lunge against the side of the trap in an attempt to get at the observer. Such behavior is exceptional, and usually the trapped squirrel lies silent and motionless as the trapper approaches. On one occasion a squirrel, which was watched from a blind as it entered a large live-trap, began dashing about within the trap with low growls as soon as it discovered that it was confined. Several other squirrels in the vicinity but outside the trap paid no heed to it and continued to pick up bait. Growling is most often given during encounters between one squirrel and another, usually underground. Such encounters occur when a squirrel is forced to take refuge in the burrow of another at some sudden alarm, or during the breeding season, when pursuit and fighting is a prominent phase of squirrel behavior. The snarling sound consists of short syllables *"churr-churr-churr"* sometimes uttered continuously for periods of minutes, variable in loudness, inflection, and length, depending on the circumstances. An observer who saw a pair of copulating squirrels at close range, said that both male and female made snarling sounds during the process.

Under stress of extreme pain or fear, squirrels give a sharp squeal. On frequent occasions in the field, squirrels have been heard to give this note at the instant of being struck by a rattlesnake. Squirrels caught in wire snares set in their surface runways gave similar squeals, sometimes several in succession. The distress squeals produced strong reactions in all other squirrels that were within hearing; they would sit up at attention and some would give alarm chirps, others would mount rocks or similar lookouts to determine the cause and direction of the disturbance.

A more subdued squeal, of high pitch and ending in a trill, is given by squirrels pursued by others. The pursued squirrel may give the note at the instant when both animals are pausing momentarily a few feet apart before the chase is renewed. In observed instances the sound had no noticeable effect on the pursuing squirrel.

Each of the chirps and calls described above is subject to much variation in different individuals and on different occasions. Calls heard in the field are not always typical of those described above, but are often more or less intermediate in character. No combination of letters can adequately represent the sound made by a squirrel. For different renditions and interpretations of some of the calls here described, see Linsdale (1946:97-103).

SEASONAL RESPONSES

Dormancy.—In the foothill habitat with its mild climate and varied food supply, conditions are favorable for year long activity above ground, and periods of dormancy are shorter and less regular than in populations of this species in other regions. At all times of year at the Experimental Range squirrel activity is conspicuous. Not all members of any one age or sex group are dormant at any one time. Individuals differ greatly in their time of dormancy, and some remain active throughout the entire year.

Records of dormancy of individual squirrels are fragmentary, as few were tame enough so that direct observations of their activity from day to day could be made, and they could not be trapped with sufficient regularity to establish proof of presence or absence. But in many instances individuals caught frequently over periods of weeks were sometimes noted to have disappeared. Then suddenly they would reappear after absences of weeks or months. Especially in January and early February of each year many old females not seen since early the preceding summer reappeared. In one instance, an adult female which had been observed daily in the fall of 1938, had disappeared on November 29, and was absent for 50 days thereafter. On January 17 it emerged from hibernation and was active for the remainder of the winter. In late August 1940, an old adult female which had been a frequent repeater disappeared, having first become fat. For three months thereafter it was not seen, and when finally recaptured late in November in its usual location, it was emaciated, having undergone reduction to just over half its August weight. Most adult females seemed to spend an even longer time in dormancy, as few are seen or trapped from June until the following January.

To illustrate seasonal dormancy, the records of a female squirrel first trapped as a half-grown young on May 3, 1939 are recorded below. It was recaptured at intervals through the summer and fall of its first year, but as an adult in 1940, 1941, and 1942 it disappeared throughout the summer and fall months and emerged from dormancy during late winter in thin or even emaciated condition.

TABLE 8.—Records of dates trapped and monthly weight of a female ground squirrel, indicating intervening dormancies.

	Dates of capture	(Average weight in grams for the month)
1939	May 3, 18, 19	313
	June 8, 10	380
	July (no records, possibly dormant)	
	August 10	360
	Sept. 26, 27	465
	Oct. 5, 13, 17, 18, 19	469
	Nov. and Dec. (no records, probably dormant)	
1940	Jan. 27	480
	Feb. 9, 13, 15, 26	457
	March 27, 29	505

TABLE 8.—(*Continued.*)

	Dates of capture	(Average weight in grams for the month)
	April 1, 9, 11, 19, 22, 23, 25	530
	May 1, 7, 8, 11, 16, 17, 21, 22, 23	699
	June 7	800
	July through Nov. (No records, dormancy)	
	Dec. 17, 19, 20	400
1941	Jan. 14, 15, 16, 18, 31	462
	Feb. 5, 6, 7, 17, 18, 19, 20, 21, 22	486
	March 5, 6, 7, 11, 17, 18, 19, 20, 21	462
	April 2, 16	535
	May 7, 28	715
	June through Dec. (No records, dormancy)	
1942	Jan. 8, 21	485
	Feb. 11	550
	March 6	537
	May 13, 18	630

Most other adult females followed the same general pattern in their seasonal occurrence as repeats in the trapping records, and in their weight fluctuations. Some emerged from dormancy in December, but others apparently spent most or all of January in dormancy before finally emerging. Even for

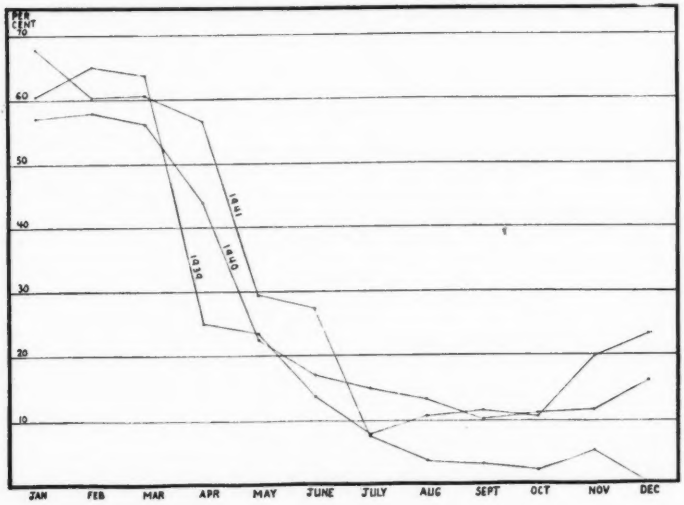

Figure 15.—Percentage of adult females in month to month trapping records for three different years. The females are in the majority during the breeding season, January and February, but are much outnumbered by young during the spring months, and undergo further decrease in summer and fall as some retire into dormancy. In 1941 the adult females comprising two-thirds of the January population had disappeared entirely by the following December.

squirrels which were active, long periods sometimes elapsed between captures, and hence from trapping records alone it cannot be definitely stated just when any individual was dormant.

Old adult females certainly spend more time in dormancy than other age and sex groups, but the entire population is active throughout the breeding season, and only at that time of year can an accurate idea of the population composition as to sex and age groups be obtained. For the fall, winter and spring of 1941-1942, the following changing age and sex ratio was obtained from the total number of captures.

TABLE 9.—Monthly percentage of ground squirrel age and sex groups in fall, winter and spring trapping records.

	Percentage of old females	Percentage of old males	Percentage of young adult females	Percentage of young adult males
October	3.16	18.7	28.0	50.0
November	.53	20.9	26.8	51.8
December	.99	23.3	21.8	54.0
January	15.7	21.3	24.5	38.5
February	21.8	13.6	30.2	35.6
March	18.5	17.9	21.0	42.6
April	21.9	19.2	23.3	35.6
May	9.3	18.6	36.1	36.1

Though adult females certainly spend more time in dormancy than males or younger females, it is probable that some old males and young of both sexes become dormant at least for short intervals. Young adults, especially females, are more abundant during the breeding season, late winter and spring, than they are during the fall months preceding. Irregular fluctuations in numbers of young from month to month in the summer, as censused by the ratio of marked to unmarked individuals, evidently are caused by a changing proportion undergoing dormancy. In September 1940 the young, then mostly approaching adult size, were 40 per cent more abundant than in August and almost as abundant as they had been in June. The apparently extensive aestivation of young in the summer of 1940 is correlated with the fact that they were in excellent condition and already early in the summer were well matured. Additional evidence of dormancy in young is provided by the fact that those recaptured after intervals of many weeks showed less weight gain than those trapped regularly over the same length of time. For a group of 14 males and 8 females trapped in July and September 1940 but not in August, average weight gains were 84 and 66 grams respectively, while in a larger group of individuals each captured in all three months, the weight gains for just the same length of time were 118 grams for males and 76 grams for females. The ratio of young males to young females trapped is high each year through the summer and fall months, and swings back in favor of the females just before and during the breeding season, demonstrating that in young as in adults the females have more tendency to become dormant than the males. Dormancy periods of young seem to be much shorter than those of adults.

It is fairly certain that there is some dormancy in adult males, though they

were never known to disappear for long periods of months as did adult females. In 1941 feeding conditions were so favorable that both males and females were unusually fat through the late spring and summer, and both sexes of old squirrels became so scarce, as compared with young that it is fairly certain each month of late summer and fall was passed in dormancy by

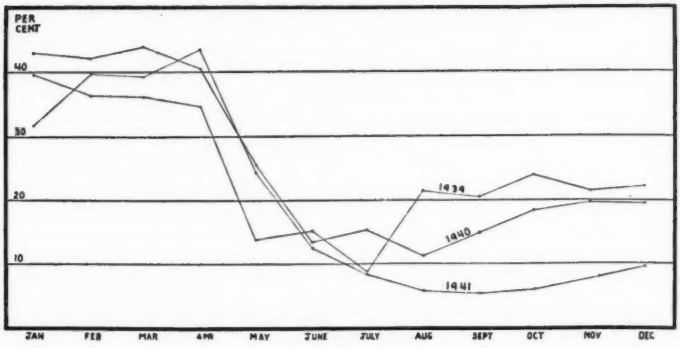

Figure 16.—Percentage of adult males in entire population in month-to-month trapping record. Trend is similar to that of females but seasonal change is less marked because a smaller proportion retire into dormancy.

part of the old male population. In 1939 and 1940 several old males were noticed to be fat and sluggish during late summer and fall, spending but little time above ground daily, and not showing much interest in feeding.

An idea of the extent of dormancy in one sex or age group as compared with another may be obtained by tracing back from the breeding season the records of groups of individuals known to have been on the trapping area a long time. For any one month absence of an individual from the records is due either to its avoidance of traps or its dormancy at the time. Avoidance of traps is not correlated with age or sex, so the differences shown demonstrate varying dormancy. In the following table, only individuals known to have been within the trapping area during most of the months involved, are included. "Number in group during breeding season," thus, does not represent the entire population, but is a selected sample of it (See Table 10).

These figures demonstrate that adult females have, in summer and fall, a consistently higher incidence of dormancy than have adult males, that the young of either sex have less dormancy than adults. It shows that dormancy was much more extensive in the summer and fall of 1941 than in 1940, and that differences between age and sex groups were accentuated in 1941 as compared with 1940. Similar data tracing the 1940 breeding population back through 1939 indicate that dormancy that year was less extensive than in either 1941 or 1940, (but are not strictly comparable since the entire area was not trapped each month in 1939).

No general conclusions as to dormancy can be drawn, beyond the fact that

TABLE 10.—Relative numbers of males and females and of yearling and old adult squirrels active during different months of the year.

	Number in group during breeding season	Percentage of breeding season group trapped in each month of year preceding											
		Dec.	Nov.	Oct.	Sep.	Aug.	Jul.	Jun.	May	Apr.	Mar.	Feb.	Jan.
Old males in 1941	50	58.0	58.0	56.0	40.0	24.0	28.0	30.0	56.0	54.0	54.0	68.0	48.0
Old males in 1942	18	38.8	50.0	33.3	27.7	33.3	44.4	61.1	72.2	33.3	61.1	72.2	55.5
Old females in 1941	78	23.1	16.6	17.9	17.9	17.9	23.1	32.1	39.8	42.3	56.4	75.6	46.2
Old females in 1942	68	0	8.8	2.9	2.9	4.4	11.7	39.7	44.1	26.5	64.7	66.2	60.3
Young adult males in 1941	92	54.4	59.7	70.6	58.7	36.9	35.9	39.1	22.8	2.2	not	yet	emerged
Young adult males in 1942	78	62.8	83.3	82.1	61.5	62.9	57.5	26.9	16.6	not	yet	emerged	
Young adult females in 1941	80	63.7	66.2	65.0	57.5	36.2	36.2	41.2	46.2	6.3	not	yet	emerged
Young adult females in 1942	69	37.7	59.4	62.3	62.3	62.3	59.4	63.8	49.2	40.6	not	yet	emerged

throughout the summer and fall many and sometimes nearly all of the old females are inactive, that some dormancy apparently occurs in adult males and young of both sexes, and that there are great differences from year to year in amount of dormancy, apparently correlated with feeding conditions and the weight attained during early summer.

Within a few miles of the Experimental Range notable differences in seasonal schedules occur in other ground squirrel populations. At considerably higher elevations in the Sierra Nevada and its foothills, a long hibernation is enforced by the severe winter climate, and aestivation probably does not occur. The sparse woods which is a feature of the terrain at the Range gives way to open rolling land within three or four miles to the west and south. Ground squirrels occur in this open land though in much lower numbers. The absence of the oaks and other trees which on the Range provide so much of the summer food and critically needed shade, must profoundly alter squirrel ecology. Casual observations suggest that aestivation occurs much more extensively.

In a study of ground squirrels of this species in the vicinity of Bass Lake, less than 20 miles away but at higher altitude, 4500 feet as against 1100 feet at the Range, Storer, Evans, and Palmer (1944) found a different seasonal schedule, with general hibernation, lasting from about November 1 to April 1. They record that "Females apparently went into hibernation before the males, since only 2 females were caught after September 25 and at least 7 males were active in mid-October. Breeding apparently occurred in the latter part of April," that is shortly after emergence from hibernation, and some three months later than it occurs at the Experimental Range. Emergence of young recorded by them was correspondingly later, as indicated below. Populations

First date of emergence of young in:	Experimental Range	Bass Lake
1938	May 3	July 18
1939	March 23	July 7

at higher elevations are evidently more regular in their seasonal schedules than are those at the Range, which vary individually in their response to weather conditions, and apparently change from year to year in their time and duration of dormancy, according to changes in the weather.

Weights.—Definite seasonal trends in weight can be traced, but some individuals do not conform closely to these. There are notable weight differences between individuals. Even within the same age and sex group, and in the same situation some may be more than twice as heavy as others. Most rapid change in weight occurs in spring, as the squirrels gain steadily through April, and May. In late May or early June they reach a peak, having gained, on the average, around 30 per cent in the course of a few weeks. During this period of gain, a varied and nutritious diet is taken, including much flower and seed material. After drying out of the forage crop, weight begins to decline. The decrease is much more abrupt if the crop of some of the favorite summer foods are short, but in favorable years the weight may be maintained at a high level through the summer. Rarely, adult males may attain a maximum weight of more than 1300 grams.

The percentage of the population undergoing aestivation probably depends upon feeding conditions and the extent to which they are able to lay up a store of fat. All squirrels known to have entered dormancy were fat and in good condition at the time of disappearance. The majority of adult females disappeared for the summer and fall, but the percentage remaining active was much higher in 1939 when they were not so fat and food was relatively scarce. In 1941 squirrels gained more weight than in 1940, and aestivation was correspondingly more complete.

Male and female weight fluctuations parallel each other through most of the year, but their trends deviate in the breeding season. Male weights are then reduced, probably as a result of continual fighting, pursuing of prospective mates, and consequent injuries and loss of foraging time. During the same period developing embryos in many of the females added to their weights. The increase due to pregnancy is not striking, as the young are relatively small at birth, and a full term litter of foetuses weighs hardly more than the stomach of an adult filled to capacity.

The following table, based on the 1942 breeding season, shows the average weights of the different age and sex groups in successive months. Numbers in parentheses indicate sizes of the samples which were of necessity small for the older groups with relatively few survivors.

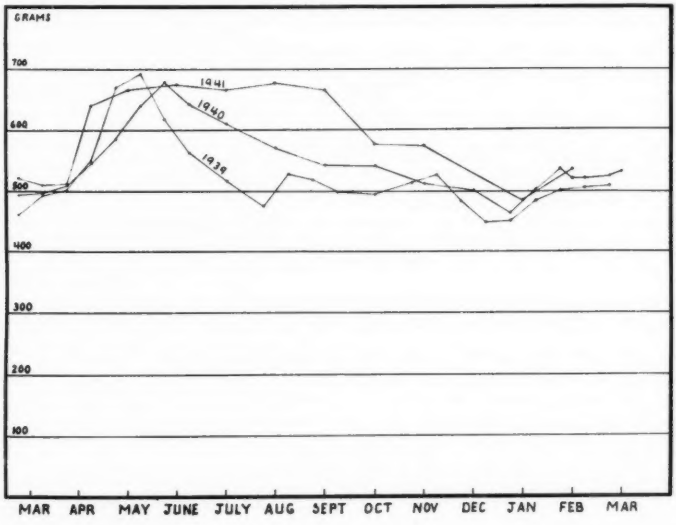

Figure 17.—Average weights of adult female squirrels trapped in three different years, showing rapid gain in late spring, and wide variation from year to year depending on weather conditions. Due to extensive dormancy in late summer and fall, samples for those seasons are small.

TABLE 11.—Average weight in grams of age and sex groups in 1942.

	January	February	March
1938 ♂♂	764.8 (6)	722.6 (5)	560.0 (5)
1939 ♂♂	668.3 (6)	603.0 (4)	595.6 (5)
1940 ♂♂	750.4 (40)	714.4 (21)	648.6 (20)
1941 ♂♂	647.4 (63)	634.3 (58)	586.1 (21)
1938 ♀♀	483.8 (10)	492.9 (8)	526.4 (8)
1939 ♀♀	511.2 (17)	552.5 (13)	527.3 (12)
1940 ♀♀	494.4 (17)	542.6 (26)	542.7 (16)
1941 ♀♀	495.5 (56)	502.9 (58)	483.6 (36)

The time of emergence of young squirrels, and their size at emergence has differed from year to year. Ability of the females to continue providing sufficient milk for their large litters of well grown young may depend largely on the forage crop. The average weights of lactating females recorded after first emergence of young varied a good deal from year to year.

In 1939 and 1946 the young were relatively small at the time of their first appearance, and may have been forced to shift for themselves at an earlier age because mothers were in poorer condition. At any rate newly emerged young were much easier to trap in 1939 and 1946 than in other years, for instance 1940, when special effort was made to catch them with but little success.

Growth rate and condition of young from year to year varies according to the food supply. The first few weeks of their activity above ground corresponds with the season when preferred foods are most abundant and when adults are gaining weight. During this time their growth is exceedingly rapid. After drying out of the forage, subsequent growth depends on the available supply of acorns, tarweed, and other summer foods. If these are scarce, as in 1939, the young may make little or no growth for the remainder of the dry season. But if conditions are favorable, with good crops of acorn, tarweed, and some late succulence remaining, the young continue to make rapid growth and many of them are already nearing adult size early in the summer.

Breeding cycle.—In the fall, testes of the male squirrels enlarge, and in late October and November most appear to be in breeding condition. Enlargement of the testes may be correlated with the change in diet from dry seed material to green newly sprouting annual plants soon after the first fall rains. At least the enlargement was observed to follow closely on this change in diet, both in old animals and in young of the year. Despite this change, males show little evidence of sexual behavior during the fall months.

None of the females appeared to be in breeding condition before the first of January. In fall and winter females have the vaginal canal sealed off from the exterior by a layer of skin, both in old adults which have survived previous breeding seasons and in young adults which have not yet bred. In the females coming in heat the genital region becomes noticeably swollen and the skin becomes somewhat discolored. In the course of a few days the vaginal canal

opens, and its lips become thickened, protruding, and turgid, and at this stage breeding occurs. Actual copulation has not been seen by the writer and must take place underground in most instances. Chasing of females by males was observed constantly during the breeding season. Yearlings breeding for the first time, seem to lag somewhat behind the old adults, as indicated by the following figures showing percentage of those appearing to be in breeding condition (with genitalia swollen and vaginal canal open) at different stages during the 1940 season.

	Jan. 1-15	Jan. 16-31	Feb. 1-15	Feb. 16-29	Mar. 1-15
Old adults	28%	54%	54%	15%	0
Young adults	10%	29%	44%	21%	0

By March, in 1940, apparently all mating activity for this season had ceased, and most adult females either were gravid or already had given birth to young.

In 1946 the breeding season was later; females were first found in breeding condition on January 22 and the last one which had not attained breeding condition was taken 49 days later on March 12. In pregnancy the swelling of the external genitalia subsides. After birth of young the lips of the vaginal orifice shrivel and adhere closely along a longitudinal slit. Before the birth of young, the nipples are minute especially in females which are breeding for the first time. In those which have suckled young during previous seasons, the nipples are more prominent, about 1 mm in length. Early in lactation the nipples are small and flesh-colored but later become enlarged, dark, and roughened. After the young are weaned, the nipples shrivel to horny knobs, and eventually the outer layer of dark, wrinkled, thickened skin is sloughed off.

Though the actual breeding season lasts nearly two months the peak is confined to a much shorter period. From year to year the time of the breeding season varied according to weather conditions. In 1938 young did not appear above ground until May 3, whereas in 1939 they were first recorded on March 23, in 1940, April 17, in 1941, April 16, in 1942, April 28, and in 1946, April 7.

In their mating activities squirrels probably are promiscuous. Each individual generally keeps to itself in its home life underground though at times two or more may use the same burrow entrance. Encounters between individuals are usually characterized by a show of either hostility or indifference; but little sociability is displayed.

Linsdale (1946:459) states: "Long periods of watching ground squirrels through the early spring seemed to show that a temporary pairing of male and female took place each spring, sometime between the end of January and the middle of March. After a pair had occupied common ground for a period, possibly as long as two weeks, the male would move to a new location. The female would then select a burrow in some inconspicuous site and prepare it for the litter of young." However, no definite evidence of this "pairing" is set forth in the same author's ten-page narrative field notes of reproductive be-

havior (*op. cit.*: 326-335). Occupancy of common ground or even use of the same burrow entrance cannot be considered as indication of pairing in view of the usually hostile demeanor of the individuals involved in such associations. Breeding males undoubtedly do move about to visit neighboring burrow warrens or even shift their headquarters under the stimulus of sexual urge, but that they direct their movements with reference to any one female except at the moment of sexual pursuit is unlikely. In the present study squirrels of both sexes were intensively observed in the breeding season, and in no case was a recognized "mate" in evidence though the individuals in question might participate in a sexual pursuit with any squirrel of the opposite sex which happened to be in the vicinity.

During the breeding season males frequently chase other squirrels of either sex, and fights are frequent. Underground encounters occur often, and are brought to the attention of a quietly approaching observer by snarling and thumping as if from a struggle. As a result of this activity squirrels lose patches of hair and suffer skin and flesh wounds. In early March almost every squirrel is badly scarred from fighting during the course of the breeding season. Females usually sustain injuries on the back and rump where they are bitten by pursuing males. Sometimes patches of hair are pulled out leaving areas of bare skin, but usually the skin is broken, leaving ugly sores as much as an inch in diameter. None of the females examined appeared to be in critical condition from the injuries. Males usually are more severely scarred than females, and facial injuries are most frequent. As a result of frontal attacks, the cheeks, lips, and supraorbital ridges of males often sustain deep wounds which are apt to be infected. The consequent inflammation and swelling makes eating difficult and painful to some of the injured animals. The sores are sometimes malodorous and trapped squirrels are attended by buzzing swarms of blow flies, which deposit eggs in the pelage around the open wounds. Some individuals known to have been in excellent condition through the early part of the winter were gaunt and emaciated with ragged pelage at the end of the breeding season, as a result of their injuries. The most seriously afflicted ones were the younger animals. This is well illustrated by a young adult caught regularly through the winter of 1940-41, weights of which on various dates were as follows: Sept. 16—540 gms. Oct. 16—550 gms., Nov. 8—660 gms., Dec. 9—650 gms., Jan. 13—650 gms., Feb. 5—640 gms., March 6—420 gms. When captured in early March this squirrel had numerous bites, some infected. It ran slowly and heavily when released, showing that it was in weakened condition from its wounds.

Occasionally at this time of year males are found so weakened that they are hardly able to escape to their burrows, and can be caught by hand. Some have even been found in dying condition. Mortality resulting directly and indirectly from fighting must be one of the factors which bring about reduction of the males, especially where the population is high. Almost every individual probably suffers some weight loss because of this activity. In April breeding activity and most of the fighting is ended. The wounds heal rapidly and become covered with a growth of new hair, and weight losses are regained.

The large scrotal testes undergo a decrease in size more gradual than their enlargement and descent in fall.

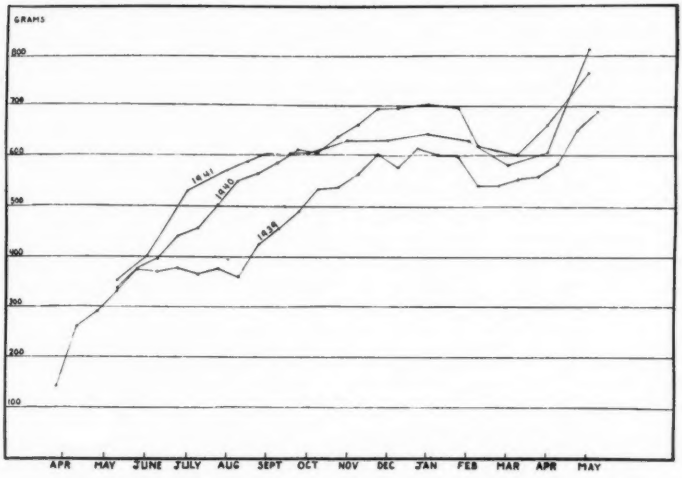

Figure 18.—Average weights of all young male squirrels trapped in three different years. Note rapid early growth, cessation of growth during critically dry summer of 1939, and loss of weight during breeding season each year.

MOVEMENTS

Effective application of control measures involves knowledge of the extent of daily movements, foraging ranges, and migratory tendencies of the species. In the present study many full days were devoted to direct observation of the movements of individual squirrels, and thousands of movement records were obtained from live-trapping. The movements shown by the trapping records are of various types which cannot be distinguished readily. These records are of most value for showing long-time movements, and are judged unsuited to demonstrate the extent of home range. Detailed direct observations on the movements of a number of relatively tame squirrels provide a better basis for showing home ranges. Figure 19 shows the ranges of several individuals of different sexes and ages, as mapped from hundreds of hours of observation. From these maps it will be seen that the range is small, only 100 to 150 yards in greatest diameter, and that most of the activity is restricted to an even smaller area in the central portion. Foraging out to the peripheral portion of the home range is relatively infrequent. Occasionally some preferred food source induces a squirrel to make unusually long foraging expeditions from its home base, beyond the limits of the usual home range. No definite or sharply defined boundaries limit an individual squirrel's sphere of activities. It usually stays at certain spots or within small areas (only a small fraction of the home

ranges shown), but at any time it may venture out farther than usual. The tendency of each to explore new territory is limited by the tendency to keep where the home burrow or other safe and familiar shelter is easily accessible. Much of the activity may be confined to the area encompassed by the burrow mounds, when food is plentiful there. Most foraging is done within a few yards of the home burrow system, or from outlying burrows used as secondary bases. As the squirrel works out from these it becomes increasingly uneasy and alert. Unusually long trips to points where food or water attract it may be made daily at certain seasons. In these instances the same route is habitually used, and travel is hurried and purposeful.

In trapping, often many captures of a squirrel were made at the same spot. The chances of one being caught were somewhat proportional to the nearness of a trap to its center of activity. The capture of a squirrel was often preceded by long and hesitant maneuvering of the animal in the vicinity, until its desire for the bait overcame its instinctive caution toward the trap. Traps encountered in outlying portions of the range were apt to be left and forgotten as the animal continued its foraging after a period of reconnoitering.

Evans and Holdenreid (1943) are of the opinion that adult male squirrels have smaller home ranges than females or young. No such tendency was found in the present study. On the contrary females were found to make less extensive movements than males of the same age group.

Being only a half mile long and a quarter mile wide, the trapping area was not well adapted to show unusually long movements, which may have often taken squirrels far beyond its boundaries where they would not have been

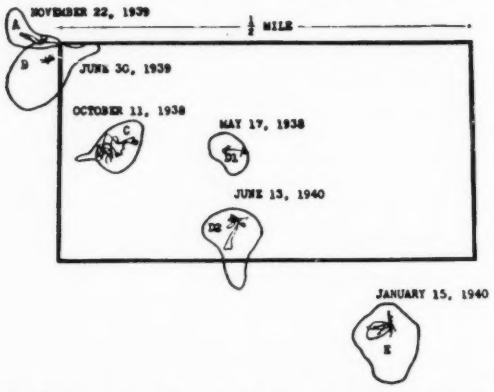

Figure 19.—Diagram showing extent of daily movement in relation to entire foraging range of several different squirrels. Records for A extended from November 22, 1939 to March 3, 1940; for B from June 6, 1939 to January 1, 1941; for C from September 13, 1938 to February 4, 1940; for D1 from May 4, 1938 to November 9, 1938, for D2, the same squirrel as preceding, after it had moved, from December 16, 1938 to August 12, 1940; for E from December 12, 1939 to August 19, 1940. Ranges of all but E shown in relation to 80 acre trapping area.

recorded. But the squirrels proved to be sufficiently localized so that their movements could generally be followed. A peripheral strip about 100 yards wide was trapped from time to time, recording many of the animals that had shifted across the borders of the study area itself.

The extent of movement recorded for any one squirrel was of course determined partly by the frequency with which it was captured, and the length of time over which the records extended. One thousand and forty-three squirrels had records extending over periods of months as follows: 1 to 2 months—10.71%; 2 to 3 months—8.72%; 3 to 4 months—5.56%; 4 to 5 months—5.94%; 5 to 6 months—4.41%; 6 to 7 months—4.79%; 7 to 8 months—4.79%; 8 to 9 months—5.93%; 9 to 10 months—4.79%; 10 to 11 months—5.66%; 11 to 12 months—5.26%; 12 to 15 months—7.35%; 15 to 18 months—5.26%; 18 to 21 months—6.71%; 21 to 24 months—5.84%; 24 to 36 months—5.66%; 36 to 48 months—1.82%.

TABLE 12.—Movements of 1043 ground squirrels, according to distance and sex.

Distance in feet	Percentage of total squirrels	Female-male percentage in sample
Less than 100	8.94	65.9 to 34.1
100 to 200	16.27	53.8 to 46.2
200 to 300	16.56	56.9 to 43.1
300 to 400	14.18	57.0 to 43.0
400 to 500	12.08	44.9 to 55.1
500 to 600	8.57	40.0 to 60.0
600 to 700	5.23	40.9 to 59.1
700 to 800	3.61	39.5 to 60.5
800 to 900	4.38	26.1 to 73.9
900 to 1000	2.28	29.2 to 70.8
1000 to 2000	7.04	21.7 to 88.3
More than 2000	.86	none to 100.0

For nearly half, the distances recorded were between 100 and 400 feet, within the probable foraging radii of the animals, and so may have involved no actual shift in headquarters. For distances over 400 feet the numbers taper off, and it is evident that the longer movements occur comparatively seldom.

Females are distinctly more sedentary than males. Among those squirrels with recorded distances of less than 400 feet, females comprised the majority, while among those making the longest movements males predominated. Young squirrels in their first year move about more than do adults. The maximum distance that each young male was trapped from its original home burrow tended to increase gradually from month to month. For 30 recaptured at intervals of 6 to 10 months the average distance moved was 971 feet, and 93.4 per cent had moved more than 300 feet. In contrast, in a group of 89 young females recaptured after 4 to 10 months the average distance moved was 177 feet, and only 12.4 per cent had moved more than 300 feet. Movements of more than 300 or 400 feet are apt to represent shifts to home ranges entire-

TABLE 13.—Average monthly movements of 826 ground squirrels.

	Adult Males		*Adult Females*		*Young Males*		*Young Females*	
	Number of movements	Average movement in feet	Number of movements	Average movement in feet	Number of movements	Average movement in feet	Number of movements	Average movement in feet
March to April, or April to May	81	187	70	105	10	268	19	109
May to June, or June to July	47	169	36	105	96	287	63	260
July to August, or August to September	30	178	26	177	106	359	70	254
September to October, or October to November	31	189	17	128	78	263	46	162

ly distinct from those originally used. From these figures and from general observations, it appears that young females have comparatively slight tendency to wander from their original home ranges, and that young males have a tendency to disperse by gradual stages, so that by the following breeding season nearly all of them have shifted to new home ranges. Often several different ranges are occupied at different times over periods of months. Movement was sufficiently extensive so that a large proportion of the young males marked on the trapping area would have moved away from it and others would have replaced them by the following year.

Squirrels were poisoned annually in early summer on the area of the Range headquarters, and for the remainder of the year few were present. But in late May, June, and July there was influx of half-grown young which occupied rock outcrops, board piles and sheds and were much in evidence until removed. For the population as a whole, shifts are more frequent in summer and fall, when limited food supply and moisture provide motivation for wandering. In winter and early spring, abundant green foliage is always available.

BURROWS

Numbers and arrangement of burrows.—Much of the squirrels' time is spent underground, and burrow systems excavated are extensive. Permanently occupied burrows usually have from ten to fifty separate holes within an area perhaps fifty feet square. Only the centrally located ones are interconnected underground; peripheral holes usually end blindly or connect with only one or two others. The larger burrow systems are nearly always situated about rock outcrops, and tunnel beneath the rocks. Digging predators such as badgers or coyotes and erosion during heavy storms, enlarge many burrow entrances to a foot or more in diameter. Nest cavities are situated within the central interconnecting maze of tunnels. Surface runways radiate from the most used burrow entrances to feeding places. At intervals along these runways are isolated holes which serve in emergency when a squirrel is taken by surprise at a distance from its home burrow. Such isolated holes have tunnels usually only two or three feet long, ending blindly with no terminal enlargement, but outwardly they have the appearance of being well used. During the course of its daily foraging a squirrel tends to loiter in the vicinity of such escape burrows, clearing out the entrances, and digging and wallowing in the mounds of earth in front of them. When the young have dispersed, many dig new small burrow systems of their own. These are apt to be situated where conditions are not favorable at all seasons, and are deserted later, but the main, well-established burrow systems are constantly in use, being occupied by successive generations of squirrels. The actual nests are usually at depths of two feet or more, in globular chambers a foot or more in diameter, and completely filled with stems and roots of fine dry grass. One, which probably belonged to an adult female squirrel, was 14 inches in horizontal diameter and 8 inches in vertical diameter, and its roof was 16 inches beneath the soil surface.

In one burrow system, probably fairly typical, there were 20 open holes of which only 8 were interconnected. The other 12 ended blindly at distances

Figure 20.—Tearing out mouthful of dry grass for nesting material.

Figure 21.—Old male squirrel carrying dry grass back to nest.

varying from 14 inches to twelve feet. Six were simple, others had one, two or three side branches. Summer nests in hollow oak trunks, usually are situated where they can be easily approached from the ground by way of horizontal limbs. In tree nests the squirrels are safe from certain natural enemies, notably rattlesnakes and badgers, and may be freer from fleas than are those which live in burrows.

In the 80 acre trapping area in March 1940, there were 3485 open holes 2786 of which were units of large, permanently occupied colonial burrow systems. The remaining 699 were outlying burrows, some separate and isolated, others in clusters of several within a few square yards, but probably not connected underground. There were 144 extensive burrow systems with an average of 19.4 holes per system. There were, on the average, 17.2 open holes and .71 burrow systems to each squirrel. Holes averaged 43.6 to the acre. Though tending to be concentrated on certain parts of the area, the holes were so distributed that it probably would have been impossible to find an area as large as an acre on which there was none.

In March 1946, all large burrow systems, and even many of the outlying escape burrows were the same ones present in 1940, but the total number of holes had undergone reduction, to 3265, with 40.8 per acre and 20.0 per squirrel. The burrow system most extensive in 1940 had 93 separate entrances. These were scattered over an area of more than 100 feet in longest diameter, and probably the majority of them were not interconnected underground. This large burrow system was situated on an open, east-facing slope at a distance from any extensive rock outcrops, though there was one centrally situated large sunken boulder. Thirteen squirrels (9 males and 4 females) lived in the vicinity. Six years later in March 1946 this same burrow system was even more extensive, having 121 open holes, but only five squirrels (2 males and three females) were known to stay in the vicinity.

The varying number of animals at such a burrow system, not closely correlated with the population density of larger areas, nor with the number of holes, rather, reflects concentration by short shifts in response to location of food sources, which vary greatly in relative abundance from year to year. In years when the crop of blue oak acorns is heavy, burrow systems located at or near productive trees are enlarged and extensively occupied, but in other years when this crop fails, the same burrow systems may fall into disuse as the animals transfer to quarters from which live-oak acorns or other foods are accessible.

Burrow associates.—A long list of terrestrial animals inhabiting the range occasionally or habitually use ground squirrel burrows for shelter. In the severe summer climate of this region many animals retreat underground to depths where moderate temperatures prevail; squirrel burrows are the most common and convenient retreats, and nearly all digging mammals of the region take advantage of them to some extent. Predators, including the coyote, badger, striped skunk and possibly the gray fox sometimes use enlarged squirrel burrows for their dens. Cottontails depend partly on squirrel burrows for shelter

and in spring when the soil is soft and easily dug, often enlarge them to a convenient size. Pocket gophers, though not at all dependent upon squirrel burrows, often dig around and through the mounds where the fertile soil may promote growth of favorite food plants. Commonly, squirrel burrow entrances are seen plugged with fresh gopher mounds, and the tunnels of the gophers often join those of squirrels. The more spacious and deep squirrel burrows when disused may be favorite locations for the nest chambers of the gophers. Kangaroo rats commonly use squirrel burrow entrances and being relatively weak diggers, take advantage of the deep and extensive excavations and merely dig their own side passages well inside them. The large burrow entrances of the squirrels are advantageous in allowing the rats to enter at high speed in times of emergency. The white-footed mouse has habitat preferences similar to the ground squirrel on the Range, and often seems to depend on squirrel burrows for shelter. Pocket mice, rock mice, and brush mice use squirrel burrows only occasionally. Woodrats occasionally take over old squirrel burrows when these are situated at bases of rock outcrops or bushes.

The burrowing owl in this region depends on squirrel burrows for its homes and was the only bird seen to use them. It is rare on the Range but common a few miles farther west in the treeless belt of the lower foothills.

Most of the local reptile species utilize squirrel burrows. The presence of these holes in sufficient numbers to provide ample shelter may be one of the critical factors which determine rattlesnake abundance. While occupancy of squirrel burrows by most of the animals heretofore mentioned has little evident effect on the squirrels, and constitutes one-sided relationships of more or less incidental significance in squirrel ecology, presence of rattlesnakes in the burrows is a matter of vital concern to the rightful owners. Gopher snakes also prefer the shelter of squirrel burrows underground. On many occasions recently killed young gopher snakes, badly mangled and lacerated, have been found on squirrel burrow mounds, where evidently they had been dropped by squirrels after being fatally bitten in underground encounters. Squirrels finding small snakes in the open have been seen to approach menacingly, as if about to attack, while scolding them. To test this reaction further a small gopher snake was placed in a cage with a tame adult female squirrel. The squirrel, with hair fluffed out, moved around it with slow, tense steps. As the snake started to crawl away, she closed in and bit it sharply on the tail, but bounded back as the snake drew up on the defensive. When the snake started away again, she closed in for another quick bite, which was delivered on the posterior part of the body, seriously injuring the snake, and causing it to coil, writhing and thrashing. The squirrel grew bolder, and moved up watching for an opening, then seized the snake's body in her forepaws, severed its spinal cord with a quick bite through the back, and again dropped it. This was repeated time after time and each successive bite was placed farther up on the snake's body toward its head, until the reptile was almost entirely immobilized and helpless, then the squirrel picked it up in her forepaws and bit it through the head and neck. After being thoroughly mangled the snake was dropped and none of it was eaten by the squirrel. When discarded its injuries resembled those of snakes found dead on burrow mounds, which almost certainly had been killed

in similar encounters. Of the snakes found killed in this way all but one were less than 18 inches in length, and half-grown or adult ones would be fully able to cope with the squirrels. On a few occasions large lizards, skinks and whiptails, were also found dead and similarly bitten on the burrow mounds. The king snake and the striped racer use the burrows but probably do not molest the squirrels under ordinary circumstances. The whiptail and brown-shouldered lizard characteristically rely on squirrel burrows for shelter.

Several amphibian species, the tree-toad, spadefoot toad, California toad, and tiger salamander are dependent largely on rodent burrows including those of squirrels for protection from desiccation during the dry season.

Of invertebrates, tarantulas (*Eurypelma*), Jerusalem crickets (*Stenopelmatus*), large beetles (*Eleodes*) and many smaller kinds habitually resort to the squirrel burrows, but nothing has been learned of their relationship to the squirrels themselves.

EARLY DEVELOPMENT

At birth the young are remarkably small in proportion to the adults. During the period March 5-15, 1940, six litters were born in captivity by

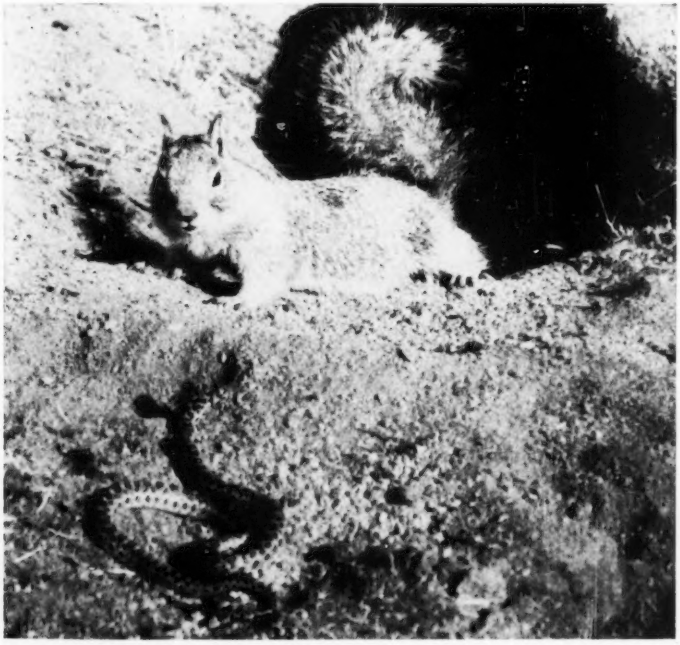

Figure 22.—Scolding a small gopher snake on a burrow mound.

females live-trapped a few days before. In each of four of these litters there were seven young; another litter had eight and still another had six. This whole lot of young averaged 8.9 grams at birth. For the different litters average weights in grams of newborn young were as follows: 8.9, 7.6, 7.2, 11.7, 9.8, 8.5. The newborn young were foetus-like in appearance, had disproportionately large heads, with eyelids and ear openings sealed (figure 23). The skin was loose and wrinkled, pale flesh color, and semi-transparent, so that the pigmented eyeball, and some of the visceral organs could be faintly seen through it. These young were naked except for downy vibrissae and minute hairs on the chin. In one that was measured, the tail was about 20 mm., hind foot 8 mm., ear 1½ mm. These newborn young were capable of slow, writhing movements. Remarkable powers of resistance in the young were shown when the mother of a day-old litter escaped from the cage. Two days later several of the deserted young still survived although they had crawled out of the nest and had ben exposed and chilled. Young one week old (figure 24) had increased in weight by 66 per cent. Though still feeble and helpless they were noticeably larger and stronger than at birth and were better able to crawl about. The dorsal surface of the heads, bodies and tails were partly suffused with dark pigment, but the ventral surfaces were still pale flesh color. Fine, dark hair was beginning to appear on the dorsal surfaces. The mystacial, genial,

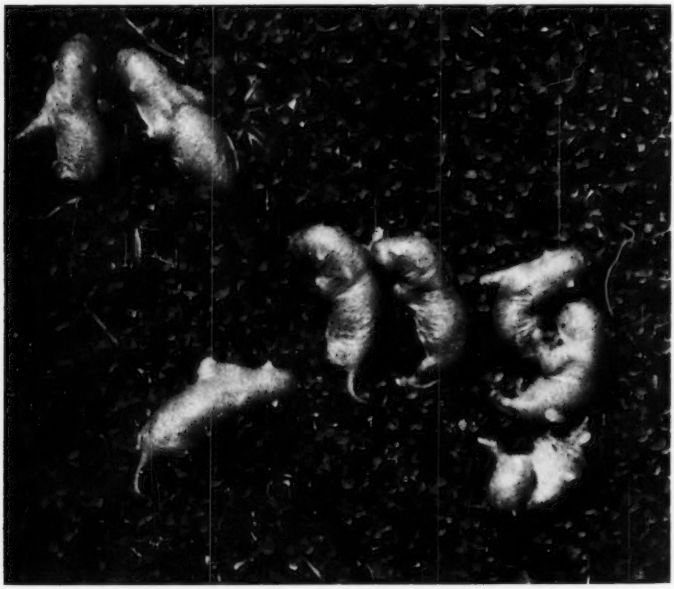

Figure 23.—Litter of newborn squirrels, blind, naked, and helpless.

and supraciliary vibrissae had become prominent, and the longest were about 4 mm. in length.

At the age of two weeks the young on the average had increased to 268 per cent of their weight at birth. They were beginning to take on a squirrel-like appearance, and had a covering of fine dark colored fuzzy hair dorsally. The vibrissae were about 6 mm. in length. At 18 days they had more than tripled in weight. The vibrissae had grown to about 12 mm.; the hair on the head was beginning to show the characteristic variegated pattern, and fine hair was noticeable on the ventral surface.

At 4 weeks weight had increased to five times that at birth and measurements were as follows: total length—148 mm., tail—50 mm., hind foot—25½ mm., ear—10 mm., longest vibrissa—17 mm., hair on body—4 mm. The tails were becoming fluffy, with hairs about 4 mm. in length. At 32 days some of the young had their eyes partly open. The measurements were: total length—177 mm., tail—53 mm., hind foot—29½ mm., ear—11½ mm., longest vibrissa—20 mm. At 34 days all had their eyes open. At 43 days the squirrels had increased in weight more than seven-fold, and their measurements were as follows: tail—61 mm., hind foot—33 mm., ear—15 mm., vibrissa—27 mm., hairs on tail—16 mm.

Throughout the period of suckling in the litter of young kept, the mother was in good condition, and was little disturbed by the handling and observing of the young. She was fed on the same kind of green vegetation which made up most of the natural food of squirrels in the wild during the same period. It is probable that the suckling young made approximately normal growth up to the time of weaning.

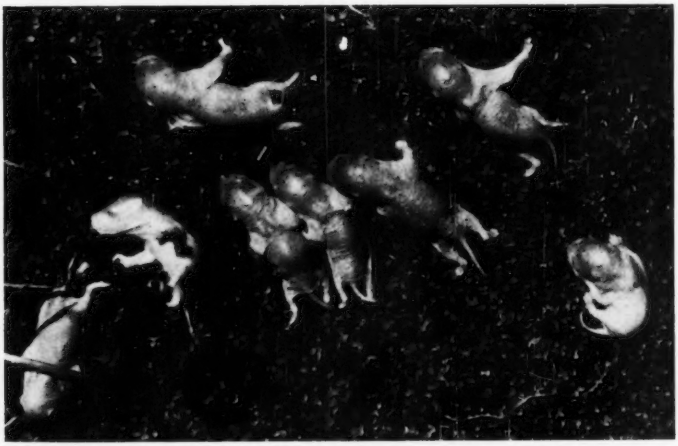

Figure 24.—Litter of squirrels one week old; still foetus-like but much larger and stronger than at birth, with hair beginning to appear.

At 55 days the young were alert and active, able to run about, and were about the minimum size of young commonly seen above ground (figure 26). They had recently acquired short molariform teeth and were beginning to feed on succulent green material, supplementing the milk diet. They attempted to bite when handled. A few days later this litter was separated from the mother, and subsequently failed to make normal growth, though some survived to an age of several months. Development after the beginning of active life above ground is best studied from records of young live-trapped in the field on successive occasions, though these records are not very complete for any one animal.

Young squirrels at the time of their first appearance above ground usually weighed somewhat more than 100 grams. But age and degree of development at the time of first emergence vary. The smallest young found above ground weighed about 70 grams. Such individuals obviously had emerged prematurely and were as yet inadequately prepared to cope with the dangers of life in the open; their gait in running was slow and unsteady, and they were easily caught by hand except when burrows were immediately available to them as shelter. None of these unusually small squirrels was known to have survived. Other young are much farther developed at the time of first emergence. In the spring of 1940 on the 80-acre trapping area, after the first appearance of a litter the area was carefully examined with binoculars almost daily for other newly emerging litters. It was found that usually several members of a litter emerge about the same time, and usually a group may be seen gathered within radius of a few feet, near burrow entrances. Some of these young were remarkably large when they first appeared, and many weighed over 200 grams

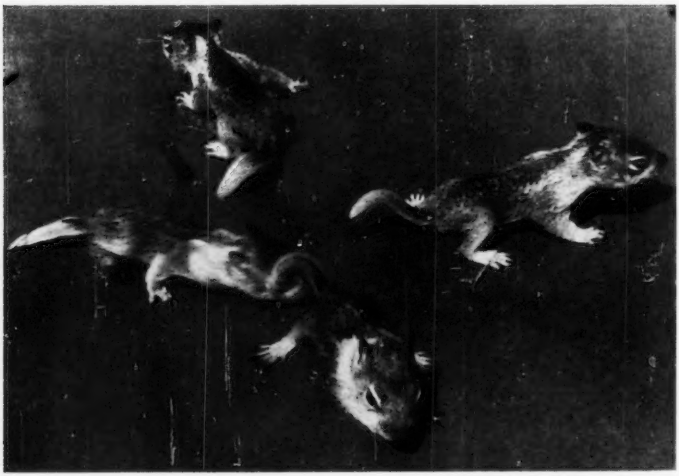

Figure 25.—Squirrels 36 days old; now able to crawl about actively, but not sufficiently developed to come above ground.

when trapped within a few days after emergence. Among the factors which may hasten or delay emergence, the weather is most important, but inadequate supply of milk by the mother, or heavy infestations by fleas and other ectoparasites in the nest might conceivably hasten the departure of the young squirrels.

At first the young tend to stay within a few feet of holes of the home burrow system and confine their activities to the area within which the holes are distributed. They are playful and curious, chasing each other, and frisking about, or sitting at attention intently observing objects in the vicinity. At this stage of their development the young are on the average considerably less wary than adults. They are already capable of giving the stereotyped reactions of adults to various stimuli. At first sight of a snake or a hawk, for instance, the young will give the characteristic "snake warning" or the "hawk warning" appropriate to the occasion. The mother of a litter often may be seen with or near the group and it is probable that her reactions to various visual and auditory stimuli influence their subsequent behavior. Young put on the alert by the mother's alarm note were wilder on subsequent occasions, and through the behavior of the mother evidently had learned to recognize potential danger in the presence of humans. The young are able to feed upon succulent vegetation from the time of their first appearance above ground. At this season foods of nutritious kinds are abundant and adults are gaining weight rapidly. From the start the young seem to take the same kinds of vegetation as do the adults and no different preferences have been noted. Seeds of popcorn flower and

Figure 26.—Squirrel 54 days old, about the size of those first emerging from parental burrows, and sufficiently developed to shift for itself above ground. Has increased in weight ten-fold since birth, but still weighs only one-fifth as much as an adult.

filaree are preferred foods at this season, and the young appear to be as dexterous as the adults in handling them. Suckling must continue for at least a week or so after the young begin to take plant food, but gradually they become more independent, wander farther from the home burrow in their foraging, and are no longer seen clustered in groups, although several may dash for the same burrow from different directions when danger threatens.

By the time the young have attained a weight of 300 grams they are fully independent and may have left the home burrow to settle down in some new location.

POPULATION

Density and composition.—Among the objectives of the present study were determining how many squirrels were present on selected areas, following their population changes at different seasons, and their trend over periods of years, and the finding of means to estimate population density of extensive areas. The extent of squirrel damage on any area is more or less proportional to the population density, which changes continually, both seasonally, and from year to year, subject to the interaction of innumerable environmental factors.

Live-trapping and marking of squirrels on the 80 acre area provided as a basis of comparison with other areas, an approximately known population density. In late winter and spring, the time of maximum activity, binocular counts were made which tended to verify the trapping records but this counting was time consuming and hardly practical where terrain was irregular. Each year in 1939, 1940, 1941, and 1942, virtually every squirrel of the adult population was trapped during late winter and spring, as shown by the fact that scarcely any new unmarked ones were caught in the latter part of the breeding season. The numbers caught reveal approximately the actual breeding population. In 1946 the area was less intensively trapped, and 221 were recorded but some still remained uncaught. The proportion of those remaining uncaught may be estimated from the ratio of new ones to others in the last two weeks of spring trapping. The actual breeding populations recorded on the area in 1939 to 1942, and the estimated population for 1946 were:

1939	251	(114 males, 137 females)
1940	304	(132 males, 172 females)
1941	296	(124 males, 172 females)
1942	283	(139 males, 144 females)
1946	245	(109 males, 136 females)

These figures, of course, do not provide a direct indication of the population density, because the factor of individual movement remains to be considered. From the ranging of those individuals intensively observed, and the trends of movement records in marked squirrels recaptured, it appears that home ranges of about 400 feet diameter may be most typical. The squirrels trapped on the study area represent not only the 80 acres within its boundaries, but also a peripheral strip of probably half a "home range" in width. If the figure of 400 feet is accepted as the typical home range diameter, then

the peripheral strip to be included would be 200 feet wide, and would amount to approximately 40 acres. The squirrels trapped on the 80 acres, accordingly, would represent the population of 120 acres. The five year average of the breeding population—275.8 squirrels—thus represents a population density of 2.3 per acre.

In view of the rapid rate of population replacement from year to year, this population was fairly stable, more so than the forage crop which provided its food. During the period of the study no sudden or extensive reduction by disease occurred, and the population showed no marked fluctuations, except in its annual cycle with the sudden appearance and subsequent gradual elimination of each year's crop of young. Nevertheless, casual observers of the local squirrel population were often heard to remark at different times during the course of the study that squirrels were "way up" or "way down." Impressions are apt to be deceptive, and especially so unless the seasonal factors of dormancy, change in foraging habits according to temperature and food supply, and the sudden rapid increment of the population by the annual crop of young, and subsequent reduction are all taken into account.

Many of the factors which tend to reduce squirrel populations act much more drastically upon the small young than upon the adults. Most of the young squirrels trapped were already at least half-grown and had survived the stages of highest mortality. But even these half-grown young were eliminated more rapidly than the adults. The actual number of young trapped each year and the percentage remaining on the area and surviving to become breeding adults were as follows:

	Number trapped	Percentage surviving to following year
1939	321	36.1
1940	339	51.6
1941	329	44.6

For the three years females comprised 45.6% of the remaining survivors that attained maturity and 40.9% of all the females survived, whereas only 31.1% of all young males survived, to be caught as breeding adults. The difference is evidently due to extensive movement of young males off the area rather than actual mortality.

The relatively low rate of survival in 1939 is clearly a result of the scarcity of food during the dry season of that year, when conditions were critical, and young squirrels made hardly any growth. The high survival in 1940 is likewise correlated with abundant food sources that year. The numbers trapped are not at all indicative of relative sizes of the successive annual crops, since fewer traps were available in the spring of 1939. Actually, young squirrels appeared to be far more abundant that year. Of adult squirrels comprising the breeding population, each year slightly less than half usually are young born the preceding year; the majority are survivors two or more years of age. The percentage of these old survivors in different years were as follows:

	Percentage of old survivors among breeding males	Percentage of old survivors among breeding females
1940	56.9	58.1
1941	45.4	48.3
1942	40.2	54.7

The 1942 population was mostly assignable to known age groups, since records had then been kept for a period of more than three years. The percentages comprised by each age group of each sex were as shown in Table 14.

TABLE 14.—Percentages of survivors from 1938, 1939, 1940, and 1941 in the 1942 ground squirrel population.

	Percentage of 1942 breeding females	Percentage of 1942 breeding males
Young of 1938, or earlier years	11.5	5.0
Young of 1939	16.5	4.3
Young of 1940	25.2	31.0
Young of 1941	46.8	59.7
Total	100.0	100.0

In each instance the "young of 1938 or earlier years" probably included some survivors from 1937, and possibly even from 1936, but these could not be definitely allocated as to age group because they were all marked after the 1938 young had attained adult size.

Of the 221 adult squirrels trapped on the area in the spring of 1946, eleven, or approximately five per cent, were marked survivors of the pre-war study. Of these, five were 1942 young (relatively few young, only 75 were marked that year), five were of the 1941 crop, and one was a survivor from 1940, hence was six years old. It is likely that there were other survivors which escaped capture because they had shifted across the boundaries of the area. Evans and Holdenreid discuss longevity on the basis of their three years study; they state that the life expectancy of these squirrels is more than two years, and quote Grinnell and Dixon, 1918, in stating that "the lifetime of a squirrel, if it dies of old age, has been estimated as five years." In the present study, the single six-year-old squirrel captured showed no signs of senility and appeared to be in excellent condition, except for blindness in one eye, an injury sustained during its first year. Therefore, the potential longevity is at least six years, and probably longer.

At times of year other than the breeding season, the factor of dormancy, differing in sex and age groups, obscures the true composition of the population. From the latter part of January through February, March, April, and most or all of May, the whole population (except for small young in the nests) is active above ground daily. It is then evident that females outnumber males. For the five years of trapping at this season males comprised from 41.9

to 49.1 per cent of the adult population trapped, and averaged 44.9 per cent. Later, through the summer and fall, all adults become scarcer, and of those remaining the males are considerably more numerous than females, more of the latter having entered dormancy. In the following table, percentage of adult males to the total adult population trapped is shown for each month of three different years. Deviations from the trends are due in part to unrepresentative or too small samples. The same months in successive years are not always strictly comparable, for instance the 1939 season was several weeks ahead of 1940 and 1941 in plant growth, and drying out of the forage crop, and changes in the squirrel population were correspondingly early that year.

During the same three years, relative numbers of adults and young among squirrels trapped showed even greater irregularity from month to month and differences between years, subject to the size of the annual crop of young, and the extent of dormancy in the adult population.

The relatively low percentages of adults in the fall months of 1941 indicate more extensive dormancy that year. In 1939 there was much less dormancy and evidently it began earlier in correlation with the early maturing and drying out of the forage.

The disappearance from the area of any squirrel might be due either to its death or to its movement elsewhere. Because of the poorly known factor of emigration from the trapping area, mortality there could not be measured accurately. On the basis of measured movements, deaths were known to be more important than shifts elsewhere, in the disappearance of a large part of the population in the course of a year. Survival on the area, until the following year, of squirrels trapped occurred in the following percentages of different sex and age groups caught in 1940 and 1941.

All adults	(597)	36.0%
All young	(662)	48.2%
Old males	(253)	26.9%
Old females	(344)	42.7%
Young adult males	(414)	41.0%
Young adult females	(248)	60.0%

Most of the young were caught in summer or fall when already well-grown, while the adults were caught mainly in the breeding season before young appeared. The apparently higher percentages of survival in the young are due to the relative shortness of the period involved. Females of both young and adults are shown to have a higher survival expectancy than males, hence the preponderance of females during the breeding season. Greater tendency of the males to make movements away from the area also accounts for part of the difference. Among the adults there was no consistent difference in survival expectancy between one-, two-, and three-year-olds.

Though the total number of squirrels on the trapping area showed only minor changes from year to year, the number occupying any one small area or burrow warren changed a great deal. Thirty-eight subdivisions of various sizes, of the 80 acres showed the following numbers in different years of trapping during the breeding season (numbers incomplete for 1946):

TABLE 15.—Proportion of males in monthly samples of adult ground squirrel population trapped.

	1939		1940		1941		Three-year Average
	Number of Adults	Percentage of males	Number of Adults	Percentage of males	Number of Adults	Percentage of males	Percentage of males
January	43	39.5	140	42.9	164	31.7	38.0
February	66	36.4	218	42.1	164	39.7	39.4
March	69	36.2	155	44.0	163	39.3	39.8
April	49	59.0	102	48.0	69	43.0	50.0
May	51	37.0	103	53.0	110	45.0	47.6
June	36	47.0	61	44.0	77	31.0	40.7
July	15	53.0	49	51.0	32	53.0	52.3
August	43	67.0	37	46.0	14	64.0	59.0
September	48	65.0	45	60.0	6	100.0	75.0
October	43	70.0	57	63.0	12	75.0	69.3
November	48	52.0	52	63.0	18	61.0	58.6
December	49	49.0	58	55.0	9	100.0	68.0

TABLE 16.—Proportion of adults in monthly samples of ground squirrels trapped.

	1939		1940		1941		Three-year Average
	Total Catch	Percentage of Adults	Total Catch	Percentage of Adults	Total Catch	Percentage of Adults	Percentage of Adults
May	136	37.8	214	48.1	205	53.7	46.5
June	125	28.8	203	30.0	194	39.7	32.8
July	92	16.5	163	30.1	210	15.2	20.6
August	134	32.0	151	24.5	158	8.9	21.8
September	151	31.8	182	24.6	131	4.6	20.3
October	125	34.4	195	29.3	152	7.9	23.8
November	116	41.4	168	31.0	139	12.9	28.4
December	108	45.3	164	35.4	95	9.5	30.1

TABLE 17.—Yearly variation in ground squirrel numbers on small areas.

	1939		1940		1941		1942		1946	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Area 1	6	5	6	8	5	7	5	7	6	6
Area 2	7	10	6	10	6	7	3	7	5	9
Area 3	1	1	2	4	5	5	6	2	2	1
Area 4	4	2	2	6	3	3	4	2	4	4
Area 5	1	3	1	0	2	3	5	3	0	5
Area 6	1	2	2	5	1	2	0	2	1	2
Area 7	0	2	3	3	1	4	0	3	4	6
Area 8	2	1	2	2	2	5	1	3	2	4
Area 9	1	1	0	2	0	1	2	0	2	3
Area 10	4	7	3	3	5	3	2	3	3	5
Area 11	4	4	5	8	5	9	4	13	1	4
Area 12	5	6	10	6	8	10	6	8	1	4
Area 13	2	5	8	6	4	13	9	5	6	7
Area 14	3	3	2	3	2	1	2	1	6	3
Area 15	6	5	3	9	12	11	7	8	4	9
Area 16	0	1	3	5	1	2	1	3	2	1
Area 17	6	3	5	3	3	7	8	6	5	6
Area 18	2	7	6	7	3	2	4	2	0	3
Area 19	2	5	3	8	2	5	3	1	6	6
Area 20	3	3	5	3	3	3	6	2	4	4
Area 21	3	3	1	1	2	3	3	2	3	1
Area 22	1	1	9	4	4	5	1	7	2	3
Area 23	3	1	5	5	5	4	3	2	1	2
Area 24	2	3	4	6	2	6	8	2	3	2
Area 25	1	2					3	0	3	3
Area 26	5	6	3	3	2	3	7	3	1	1
Area 27	2	1	2	4	4	3	1	0	0	0
Area 28	0	0	1	1	2	2	4	1	0	0
Area 29	8	9	8	10	5	14	8	8	6	4
Area 30	0	0	1	5	2	3	0	2	1	2
Area 31	2	4	0	0	1	0	2	2	0	1
Area 32	5	5	4	2	0	2	2	2	0	0
Area 33	2	4	4	4	1	2	1	1	2	1
Area 34	1	2	1	5	1	4	2	3	6	3
Area 35	0	0	0	2	1	1	2	2	0	0
Area 36	3	8	3	8	8	7	4	4	3	2
Area 37	3	5	2	3	3	1	3	5	4	4
Area 38	0	0	1	0	0	0	1	0	0	0

Over the Range as a whole, squirrel populations were found to be very unevenly distributed, in correlation with abundance and variety of food supply, and presence of adequate shelter. Greatest concentrations were along the larger swales, especially where there were nearby oak trees, and rock outcrops, providing a combination of good feeding grounds and protected burrow sites. Open oak woods with numerous rock piles or outcrops also provided favorable habitat. Dry, steep slopes, canyon walls, and extensive stretches of thick chaparral, or of open grassland with shallow soil, are habitats little used by the squirrels. Degree of utilization of the forage crop by cattle appeared to be unimportant as a factor determining the abundance and distribution of the squirrel population. The "Natural Area" protected from grazing over a period

of years had one of the lowest population densities of the entire Range, but part of it was poisoned annually, and the remainder was brushy. Very close grazing, by sheep for instance, might be expected to bring about a reduction of squirrels by reducing the quantity and variety of their food supply. But the "close" and "moderate to close" utilization of the more heavily grazed pastures (1 and 3) apparently favored their abundance, as these areas were the most densely populated. Increase of filaree and other broad-leafed herbs at the expense of grass species, which occurs under heavy grazing, would favor the increase of squirrels. Favorable distribution of oak trees, rocks, soil and slope, have probably been more important factors in affecting the squirrel populations.

For several pastures of the Range where counts of adults were made in the winter and spring of 1939 and 1940, and again in early 1946, the averages shown in Table 18 were obtained.

TABLE 18.—Ground squirrel numbers on different pastures of the San Joaquin Experimental Range.

Area	1939-1940		1946	
	Number of squirrels	Squirrels per acre	Number of squirrels	Squirrels per acre
80 acre study area and 40 acre border	278	2.3	245	2.0
Pasture 2	406	1.8	243	1.1
Pasture 3	365	2.4	98	.6
Pasture 4	364	.6	107	.4
Pasture 5	294	1.2	82	.3
Pasture 6	469	1.5	103	.3
Pasture 8N	147	1.6	39	.4
Pasture 8S	137	1.4	49	.5
Pasture 9N	85	.9	26	.3
Pasture 9S	87	.9	16	.2
Pasture 10N	115	1.3	19	.2
Pasture 10S	164	1.8	45	.5
Total	2911 (1.51 per acre)		1072 (.55 per acre)	

The number of squirrels for each pasture was calculated from the average per minute recorded in strip counts made by walking across the areas, and compared with the average per minute recorded on the 80 acre study area, where the number was known from live-trapping. The 1946 figures are based on much fewer counts than those of 1939-1940. But the indication that population density in many pastures had undergone sharp reduction was borne out by general impression in driving through them. In the absence of observations throughout most of this interval, there seems no plausible reason why the population of a large portion of the Range should have been reduced to about 37 per cent of its 1939-40 density, and why during the same period, the trapping area underwent only slight reduction.

The annual peak in numbers of squirrels comes in late February and March when most or all of the females have given birth to litters averaging seven, presumably almost quintupling the population. No definite instances of non-breeding females were recorded. The average population of just over 1½ per acre as estimated for the Range in 1939 and 1940, would be increased to nearly 7½ per acre. Many of the small young must perish before they are old enough to come above ground. Evans and Holdenreid (1943) suggest that still-births may be an important factor. On several occasions remains of young too small to leave their nests were found on burrow mounds dead and partially eaten, perhaps by adult squirrels. Unfavorable weather and disease may be important causes of early mortality, but with the data now available it is impossible even to estimate the proportion of young which die before they are old enough to come above ground.

The most vulnerable stage in the squirrel life cycle is probably the period after first emergence from the nest burrow. General emergence of young takes place within a period of a few weeks. They usually first appear at many different burrows on the same day, and for weeks thereafter the numbers steadily increase. These inexperienced young are easy prey for predatory birds and mammals, of which the food requirements are much increased at that season due to the fact that they are providing food for their young as well as for themselves. The proportion comprised by squirrels in the diet of several predator species increases sharply at the time the young squirrels emerge.

Effects of predation.—The red-tailed hawk is by far the most important raptor species in its effect on ground squirrels in this locality. In a study of red-tailed hawks on the Experimental Range (Fitch, Swenson and Tillotson, 1946) it was found that the ground squirrel was the favorite food species; of 4036 pellet prey occurrences 1049 were squirrel and of 625 nest prey items 380 were squirrel. It was calculated that ground squirrels comprised over 50 per cent by weight of the year round diet, and that a pair of hawks in their 320 acre territory would annually eliminate about 144 squirrels, or .45 per acre. As virtually the whole Range falls within the territories of paired adult hawks, and there is an additional but variable population of wandering adults and unpaired young, the figure is thought to be conservative. It amounts to only 7.7 per cent of the annual increase calculated for the 1939-40 population.

In this particular region, the rattlesnake is the most important of all ground squirrel predators. Attempt was made to determine numbers of rattlesnakes by marking and releasing many of those found; 679 were released and 156 of these were recaptured a total of 203 times. From the ratio of marked snakes recaptured to others on a 160 acre sample area, making due allowance for movement, it appeared that the population density was slightly more than one rattlesnake per acre.

Among 19 prey species identified from scat and stomach examinations of rattlesnakes, ground squirrels were by far the most freqently represented, and comprised 116 of the 285 items. While mice and lizards made up most of the food of the smaller snakes, ground squirrels and occasional young rabbits

comprised nearly all the food of the large ones. On the basis of weight, ground squirrels were computed to be 68.8 per cent of the total food taken.

Frequency of feeding in rattlesnakes is not well known. Storer and Wilson (1932:169-173) present figures on the food consumption of three in confinement, for a combined total of 7 years of feeding. These snakes took a total of 65 rats and mice, average 9.29 per snake per season, with an average weight of 99.5 grams per meal. Only one snake weight is given and this individual consumed an annual average food weight 2.63 times its own original body weight, but no record of its growth is given. At the Experimental Range, three adults taken soon after their emergence from hibernation in 1946 were kept confined in an outdoor concrete pit for a year, and were fed mainly on pocket gophers and kangaroo rats. Food was weighed before being offered and weight of each snake was also recorded at the beginning and end of the season, and several times between. Attempt was made to simulate natural conditions in the pit, which was provided with an insulated box where the snakes took refuge at times when temperature was high. The experiment was not entirely satisfactory, as one snake was known to have fed before it was captured in the spring, and neither of the two females produced young. The data obtained seem to indicate that an adult rattlesnake requires a prey weight of at least twice its own body weight to maintain itself in good condition throughout the growing season. The average weight of a large series collected in spring was about 200 grams; their average food requirement thus might be around 400 grams apiece or 440 grams per acre with the population density indicated for this place. If the diet consists of 68.8 per cent squirrel, as indicated by the sample

Figure 27.—Remains of squirrel partly eaten by Red-tailed Hawk.

obtained, then it might be concluded that rattlesnake predation annually eliminates about one or two young squirrels per acre.

However, during the dry season, mid-June to October, hardly any rattlesnake feeding records were obtained. Practically all the records of predation on ground squirrels were in spring and pertained to small young squirrels. Presumably the snakes continue to feed throughout the summer, but by midsummer most young squirrels have grown so that they would be too large for all but the largest rattlesnakes to swallow. In the second half of the growing season predation on ground squirrels must be much reduced.

On the other hand field observations have shown that frequently squirrels are bitten and killed but not eaten by the rattlesnakes. The young as well as the adult snakes occupy squirrel burrows and are always ready to strike any squirrel which comes within reach, and even the smallest rattlesnakes have enough venom to kill adult squirrels. Sudden close-quarter encounters with rattlesnakes lying in the burrows must often occur. In such underground encounters, squirrels must be at a tremendous disadvantage in detecting and avoiding snakes in the dark. It was often noticed that squirrels released from live traps at dusk had difficulty finding their way about. In moving through their burrows they must be guided largely by tactile sense, using their elongate vibrissae. Rattlesnakes have eyes adaptable to low light intensities, and are able to detect approach of a rodent by the temperature-sensitive pit, even in complete darkness. Rodents struck by hunting rattlesnakes are ordinarily released, and tracked down after death. In many instances, the victim wanders too far to be found or dies in an inaccessible place. Presumably in such cases the snake continues to prowl until other prey has been obtained.

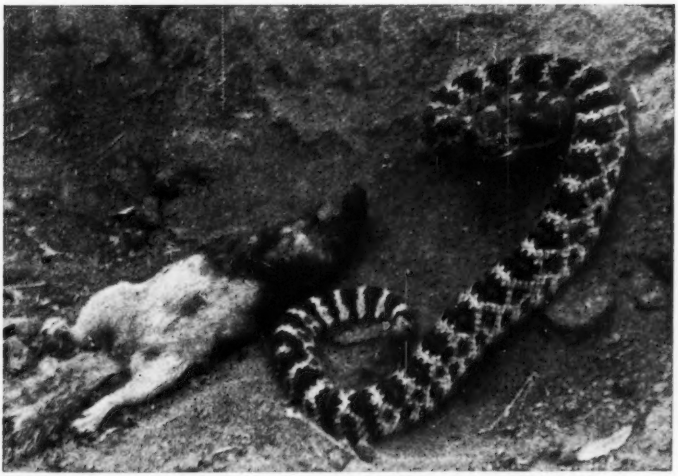

Figure 28.—Rattlesnake and adult squirrel partly swallowed and disgorged by it.

Several mammalian predators, the coyote, gray fox, badger, and bobcat, are all fairly common on the Experimental Range, and each includes a substantial proportion of ground squirrel in its food. Coyotes have been subject to control on the Range since 1936, when 35 were caught in 30 days trapping. Numbers recorded taken other years were as follows: 1937-1938, "about 30"; 1938-1939, "about 30"; 1939-1940, 13; 1940-1941, 13; 1942, 7; 1943, 5; 1944, 8; 1945, 1. Greater numbers were trapped and poisoned on adjoining ranches. In 1173 coyote scats there were 1924 occurrences of vertebrate prey, 254 arthropod occurrences, 30 occurrences of carrion of large mammals, and 42 occurrences of plant food. Many of the arthropods were of kinds found on carrion and were probably taken accidentally, but the Jerusalem cricket occurred 116 times. The ground squirrel was the most frequently occurring of all scat items, with 414 representations. Assuming that each prey occurrence represented one individual animal, and estimating percentage weight of the total food comprised by each kind of prey, on the basis of average weight of each, ground squirrel comprised 31.2 per cent, and was second only to rabbit. As each coyote consumes the equivalent of one large ground squirrel daily, and nearly one-third of this food actually consists of ground squirrel, it appears that a coyote must eliminate approximately 120 ground squirrels in the course of a year. In each of the years 1939-1940 and 1940-1941 when 13 coyotes were removed from the Range, the total population from spring until removal the following winter must have been between 15 and 20 animals. Accepting the lower figure, there might have been, on the 4600 acre area of the whole Range, one coyote to about 300 acres, and coyote predation would have eliminated .4 squirrels per acre annually.

Gray foxes were probably as numerous as coyotes. In June 1938 a fox den with seven half-grown young was located in a deep crevice of a rock outcrop on a brushy slope. Scattered remnants of prey in the vicinity included tufts of rabbit fur, quail feathers, and especially ground squirrel remains, characteristically the tail tip only. In a small collection of fox scats made in 1940, there were 102 vertebrate prey items of which 89 were rodent and rabbit, 10 were birds and 3 were reptile. Plant food, arthropods and birds all made up larger percentages of the fox's food than they comprised in that of the coyote. Ground squirrels were computed to make up 24.3 per cent by weight of the vertebrate prey items taken, excluding from the computations 101 occurrences of arthropods, carrion, and plant food of which the weight could not be accurately estimated though it probably made up only a few per cent of the total.

Nearly every old and large squirrel burrow system had holes with entrances greatly enlarged by badger digging. The fresh diggings were noticed almost daily in winter and spring. Several times ends of squirrel tails, dropped by a badger that had finished its meal, were found on the freshly excavated mounds. Squirrels cornered in shallow, blind-ending escape burrows seemingly would be easy prey for a badger, but those in main burrow systems with many connecting passages could usually escape. Even in burrows around rock outcrops signs of badgers having dug out squirrels have been observed. Some squirrels

may be dug out while dormant, and perhaps others are cornered in blind ending crevices in the rocks. The badger is probably one of the most important squirrel predators locally, but nothing is known of its population density or the actual percentage of squirrels in its food. Bobcats are fairly common locally perhaps outnumbering foxes or coyotes, but they tend to stay in the more brushy and rocky areas where the squirrel population is lowest, and are more apt to hunt rabbits, woodrats, or pocket gophers.

Several other predators are known to take their toll from the squirrel population, but singly or combined they are of only minor importance. The golden eagle, ferruginous rough-legged hawk, prairie falcon, and marsh hawk are all known to hunt on the Range occasionally but the total number of squirrels killed by them must be small. Among 41 prey items recorded in two Cooper hawk nests, only one was a squirrel. Among 1471 vertebrate prey items in horned owl pellets only 13 were squirrel, though predation on them is more severe when the owls are nesting, as in 1939 ground squirrels comprised 11 of 67 prey items from four different nests, and were recorded from three of the four nests (Fitch, 1940). Gopher snakes are less common than rattlesnakes on the Range, and were found in a ratio of one to 3.7, probably a little less than one to three acres. Among 72 gopher snake prey items of 12 kinds, there were 5 ground squirrels, which were calculated to make up 28 per cent of the food weight. If the gopher snake's food requirement is similar to that of the rattlesnake, a prey weight of 400 grams to a snake would be taken, and this would amount to 120 grams per acre. The 28 per cent of this weight comprised by ground squirrel would constitute about one young squirrel to six acres. Among 116 barn owl pellet prey items there were no squirrels, nor are the raccoons, skunks, weasels, opossums, and king snakes that occur in this locality known to prey upon them.

To sum up predation data, the breeding population of about 1.51 squirrels per acre (with more than 55 per cent females) in 1939 and 1940, had a potential annual increase of about 5.8 per acre, of which known predation factors could have accounted for the following numbers:

TABLE 19.—Numbers of ground squirrels eliminated by predators.

Kind of predator	*Number of squirrels per acre annually eliminated*
Rattlesnake	2.00
Red-tailed hawk	.45
Coyote	.4
Gray fox	unknown
Badger	unknown
Gopher snake	.17

Data on the numbers and feeding habits of two important squirrel predators, the badger and gray fox, are insufficient even to estimate the number of ground squirrels destroyed by them. It is fairly certain that neither eliminates more than one per acre annually. Major predation factors, as here crudely

measured or estimated, appear to account for a little more than half the annual increase. Other predators combined (including the horned owl and Cooper hawk) could not be expected to take more than a fraction of one per acre.

Other causes of death are obscure. Several times particularly after periods of unusually cold and wet weather in winter and spring, dead or dying squirrels have been found, with no external injuries or other apparent causes. One sent to the Fish and Wildlife Service Disease Research Laboratory at Los Angeles was found to have extensive pneumonia, which presumably was the cause of death. Wetting and chilling in the nests and loss of feeding periods may be contributing causes to deaths resulting from unfavorable weather and disease induced by it. At all times of year, dried and partly decomposed carcasses of squirrels often appear on burrow mounds, cast out by other occupants after the animal has died underground. Occasional squirrels have been found in weakened and greatly emaciated condition, while other normally healthy ones lived in the same or adjacent burrow systems. As one example, a large adult male trapped on July 12, 1940, weighed 650 grams and appeared in normal health, but 36 days later it was found so weak and emaciated that it was easily caught by hand as it feebly attempted to reach its burrow; it then weighed 390 grams. Series of squirrels collected on the Range and examined each year by the California State Department of Health have not revealed the presence of tularemia or sylvatic plague.

SUMMARY

California ground squirrels were studied at the San Joaquin Experimental Range in 1938, 1939, 1940, 1941 and the early part of 1942, with a small amount of supplementary field work in 1946. During this time, on an 80 acre intensive study area, 1552 squirrels were marked, and captured a total of 15,936 times; census counts, feeding records and general observations were recorded from this same area and from many other parts of the Range.

The quantity of food consumed by an individual squirrel was found to vary greatly according to conditions. Squirrels in confinement, fed upon dry wheat in summer, took on the average about twenty-two grams daily, and some fed upon natural green foods of preferred kinds consumed from 10 to 100 grams (representing a dry weight of 6 to 25 grams). Others intensively observed in the field during entire days of feeding took amounts estimated at from 27 to 115 grams (representing dry weights of 7 to 29 grams). In a half-acre ground squirrel enclosure stocked to represent a concentration of 12 squirrels per acre, average yield of vegetation was reduced by 1058 lbs. (dry weight) per acre, annually, more than ten times the amount the squirrels might actually have eaten. Much of this loss must have been due to stunting of vegetation eaten back during early stages of growth, and to trampling and cutting of plants not actually eaten; on the open range in competition with stock, damage per squirrel would be somewhat less.

Sixty-three kinds of plants were recorded in the year-long feeding of the squirrels, but a few species, filaree, acorns, tarweed, eriogonum, popcorn

flower, and seeds of ripgut grass make up the bulk of the diet. Use of many of the foods is limited to a short season. Competition with stock is most severe during late fall, winter and spring, but is much reduced in the dry season, when feeding is diverted from forage plants to acorns, tarweed, turkey mullein and cast seeds of ripgut grass. Squirrels are highly selective in their feeding, and choose only the more nutritious foods.

In their daily activity squirrels are much influenced by temperature. In winter they are above ground only during the middle of the day, but in summer they are most active in early morning and late afternoon.

These squirrels are generally hostile toward one another. Chasing and fighting occurs frequently at all times of year and especially in the breeding season, but there is no territoriality. Home ranges are not sharply defined but are usually 100 to 150 yards in diameter. Some individuals may spend their entire lives within the same home range. Others may shift repeatedly. Males are less sedentary than females, and young of the year move about more than adults. Voice plays a prominent part in social behavior. Different kinds of warning chirps are given to indicate presence of a snake, raptorial bird, or mammalian predator.

Seasonal dormancy occurs in this region, but in only part of the population. Extent and duration of dormancy vary a good deal from year to year according to weather and feeding conditions. Aestivation-hibernation occurs in a large proportion of adult females, from early summer until December or January. Adult males and young of the year are dormant in smaller numbers and for shorter periods. Squirrels become fat before entering dormancy, and favorable feeding conditions, as in the summer of 1941, favor extensive dormancy. Squirrels emerge in thin or emaciated condition after months of dormancy.

The entire population is active during late winter and spring. Breeding occurs in the latter half of January and early February. The breeding population was between 2 and 3 per acre each year on the study area, but was lower on other parts of the Range. Young, averaging seven per litter, emerge above ground usually in April, and grow to nearly adult size during the summer. The following winter the surviving young comprise about half the breeding population. Elimination is most rapid at the time young first appear above ground. The principal natural enemies of ground squirrels in this area are the coyote, gray fox, badger, rattlesnake, and red-tailed hawk; the bobcat, gopher snake, horned owl, and Cooper hawk are less important. Attempt was made to determine the population of each of these predators, and the numbers of squirrels taken by them. No basis for estimating populations of badgers or gray foxes could be found, and the proportion of squirrels in their diet is not well known. Frequency of feeding in the rattlesnake is not well known either, and the population figure obtained is questionable. Best estimates of predation possible with the data at hand seem to account for about half the annual increase of ground squirrels. Apparently many are eliminated through other causes, of which diseases and weather may be important.

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The Molting and Fur Growth Pattern in the Adult Silver Fox

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In a previous article (Bassett, Pearson and Wilke, 1944) a description is given of molting, fur growth and priming in the adult silver fox. This description is general rather than detailed in character. It furnishes little basis for making comparisons between groups of animals in which the pelage changes are artificially accelerated or delayed because it does not divide this process into developmental stages.

If comparisons are to be made of the molting and fur growth pattern of individuals in experimental lots, it is essential that such criteria be set up and the different stages precisely defined. The assignment of a numerical value to each stage of such a pattern makes possible the use of data in presenting the results graphically—a procedure that assists greatly in interpretation. Of even greater importance is the fact that when the molting process is broken down into separate and distinct stages it is possible to compare the step by step progress of different experimental groups.

Materials and Methods

Ten adult silver foxes (3 males and 7 females) selected at random from the Station herd, exposed to natural light, were examined at weekly intervals from May 12 to pelting to determine the character and extent of visible changes taking place in the shedding of old and the growth of new fur. The changes that occurred were gradual, and each step merged imperceptibly into the next.

Stages 1 to 16, inclusive, were determined by visual examination, at a distance, of the individual fox. Stages 17 to 20, inclusive, were determined entirely by skin color—a procedure requiring catching and examining each animal. As the molting cycle progressed a description was written indicating the changes that occurred and the approximate time of year each stage could be expected to appear. After the written description of each stage had been completed it was compared with the appearance of several other adult foxes just entering that particular stage of molt. Later the drawings shown in plate 1 were made solely on the basis of the written description.

The mean molting stage for all 10 foxes was obtained by adding numbers

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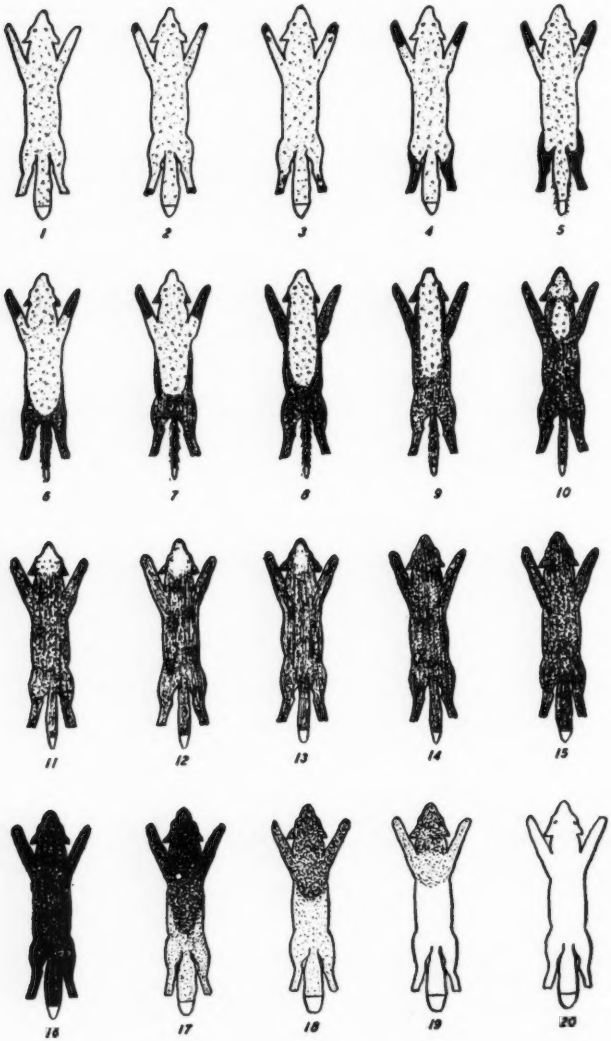

PLATE 1.—Stages in the molt and fur growth pattern of adult silver foxes.

designating the molting stages of the 10 individuals and striking an average. When an animal had reached complete primeness (stage 20) it was carried along at that stage indefinitely. Animals pelted for purposes of comparison before primeness was reached were eliminated from further consideration after pelting.

STAGES IN THE MOLT AND FUR GROWTH PATTERN

Plate 1

Stage 1.—The adult silver fox is equipped with a fully prime and attractive coat of fur by late November or early December. Important changes take place during the winter, spring, and well into the summer. The jet black color of the guard hair shaft fades to varying shades of black and brown. The silver bar loses its luster and becomes yellowish white or straw color. The bushy tail becomes smaller and more clublike in character. The appearance of the pelt as a whole progressively deteriorates. This is a description of the adult silver fox pelt in early April, just before molt starts.

Stage 2.—In late April or early May, darkened areas which represent new hair first appear on and between the toes of all four feet. Later these areas increase in size and spread out until each foot is completely darkened.

Stage 3.—By late May, both fore and hind legs are dark in spots as the old fur is rubbed and the new hair becomes evident. Some guard hair and underfur have loosened and are dropping from the posterior portion of the tail.

Stage 4.—Both front and hind legs, from feet to carpal and tarsal regions, are well shed out by June 15, and there is a loosening of both guard hair and underfur from the base of the tail, the lower thigh, and the tail itself.

Stage 5.—Molt is progressing slowly in the hindquarters. The guard hair and underfur are disappearing from the buttocks, and from the mid-thigh to the tarsal region. Approximately one-third of the old fur from the tail has been lost. This stage in the adult fox molting cycle is usually completed by July 4.

Stage 6.—The underfur is practically gone from the ears, the hips, the thighs, and the tail by July 25. Some underfur on the abdomen is missing.

Stage 7.—The old fur is gone from the ears by August 10 at the latest, and except for a slight dustiness they resemble black velvet in color. There is no underfur remaining on the buttocks, the thighs, or around the anal region, from the pelvic bones posteriorly, and ventrally to the tarsal region.

Stage 8.—Molt in stages 8 to 12 occurs with great rapidity. In 1945, for example, among 10 animals, stage 8 was first seen on July 27 and last evidenced on August 10. In the same group, stage 12 was observed on August 10, and the last animal so graded was seen August 31. Stages 9, 10, and 11 had occurred in the interim.

In stage 8, the abdomen is shed out. Underfur of the thoracic and lumbar regions is loose and ragged in appearance. There are only a few old guard hairs on the hips and thighs. The forequarters give the effect of low shoulders, since enough underfur has been shed so the guard hairs lie fairly flat. New fur growth of the tail is making rapid progress.

Stage 9.—Underfur of the neck and shoulders is thinner. Fully half the underfur from the lumbar and thoracic regions is gone. Molting during this period is characterized by the loss of underfur in large patches.

Stage 10.—Guard hair on the body is still plentiful, but the underfur is practically gone except for the neck and shoulders. The animal is thin and ragged in appearance.

Stage 11.—The animal is dusty in appearance. Underfur is practically gone from the neck and shoulders. The guard hair is gone from the hips, but is present in great quantities over the rest of the body. New hair is increasingly evident on hips and thighs.

Stage 12.—A small amount of old guard hair is still present on the ribs, back, and loin. Molting of the neck and shoulders is nearly completed, and new hair in that region is easily distinguished. The tail is dark with new fur. Hair on the face is being shed slowly, as indicated by the decreased fur density of that region.

Stage 13.—By the first week in September all old underfur is gone, as are most of the guard hairs. A few of the latter scattered at random over the body have caused us to name this the "few and far between stage." Guard hairs are still being shed from the face. The animal is dusty in appearance. New hair growth on body and tail is dark and abundant.

Stage 14.—Shedding is completed by mid-September. New fur growth, largely guard hair, is plentiful and about half an inch in length.

Stage 15.—Silvering is beginning to show up plainly in the new hair growth by late September or early October. Some guard hairs are 1¼ inches long. The fur growth of the tail is about half completed, and the tip is very prominent. Some dustiness of the fur is still apparent.

Stage 16.—New fur growth all over the body and on the tail is about three-fourths completed by October 20. The underfur growth the past two weeks has been very rapid. Dustiness in the animal's appearance has practically disappeared.

Stage 17.—Stages 17 to 20, inclusive, are determined almost entirely by skin color. The tail appears to be completely furred out, and the body is well furred and fluffy. Fur growth is nearing completion. Guard hairs on the shoulders are about 2½" long. The skin of the neck and shoulders is a dark slate in color. This stage is prevalent in late October and early November.

Stage 18.—By November 10, all fur growth appears to be completed. Skin color now becomes our guide in determining when pelt primeness has been reached. Color of the skin on hips and loins is a light slate; on the neck and shoulders it is a slate or slate blue.

Stage 19.—The hips and loins have reached full primeness, as evidenced by the creamy white color of the skin. The shoulders and front legs, however, show a faint bluish cast, while the neck is a slightly darker shade of blue. Complete pelt primeness thus has not yet been reached. This stage in fur growth and priming is generally reached between mid-November and December 1 in the latitude of Saratoga Springs, N. Y.

Stage 20.—The skin on all portions of the body is a creamy white color, the animal is fully prime, and the pelt is ready to take. This point may be reached anytime between November 15 and December 10, depending upon the individual fox. Most adults at the Station, however, are not completely prime and ready to be pelted until about December 1 or later.

RESULTS

In making these observations, two facts of interest stand out. First, there is a definite molting pattern followed, but there are many individual variations from that pattern. Fox vixen 24D, for example, required 56 days to pass through stage 4 (May 18 to July 13), while male 373F passed through the same stage in 7 days (May 25 to June 1). Once stage 14 (complete shedding) had been reached, however, rapidity of fur growth became more or less uniform.

Second, there was a slight but distinct tendency for adult vixens that had undergone oophorectomies the previous spring to prolong one of the earlier stages of the molting cycle beyond the time normally required by average foxes (table 1).

TABLE 1.—Delay in molt experienced by adult vixens on which oophorectomies had been performed.

Vixen No.	Molt unduly prolonged			Total days	Approximate time normally required to complete stage given (in days)
	Stage	From	To		
350C	4	May 18	June 15	28	20
350C	5	June 15	July 31	46	29
1005F	3	May 12[1]	June 15	34	20
322A	5	June 22	Aug. 6	45	29
102A	2	May 18	June 15	28	22
40B	3	May 12[1]	June 15	34	20
190A	5	May 12[1]	June 30	49	29
296F	4	May 18	June 15	28	20
	5	July 5	Aug. 6	32	29
676F[2]					

1 or earlier, since first observations were made on this date.
2 Showed no undue delay in molt at any stage.

ACKNOWLEDGMENT

We wish to acknowledge with sincere thanks the help given by Mr. C. Ford Wilke in arranging the text and improving the drawings.

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Amphibians from Burkes Garden, Virginia

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On two occasions, in the summers of 1946 and 1947, the writers had the opportunity to spend some time making biological collections in Burkes Garden, Tazewell County, Virginia.

The area known as Burkes Garden is a high, almost completely enclosed, limestone valley located in the northeastern portion of Tazewell County. Physiographically, the region is characteristic of the Middle Section of the Valley and Ridge Province, and is situated on the west side of Clinch Mountain near its northern end. Burkes Garden is well known geographically, and may be found on most maps of southwestern Virginia.

From a geological standpoint, Burkes Garden is a large, oval, anticlinal valley, formed by solution of the thick (3500 feet) beds of Ordovician limestone—the only soluble rock found in the five by eight mile bowl. The valley floor averages about 3200 feet above sea level, and the mean elevation of fringing Garden Mountain is approximately 4000 feet. Dr. Byron N. Cooper has recently published a very thorough study of the geology of Burkes Garden[1] from which more detailed information may be obtained.

Because of the limestone floor of the valley, much of the drainage is subsurface. The chief stream, Burkes Garden Creek, leaves the valley through the single water gap, on the western edge, and is tributary to the New River through Wolf Creek.

Due to the high elevation of the valley, the climate is cooler there than at any other comparable area in Virginia. Extremes in temperature over a period of forty years are –27° F. and 97° F. Rainfall is fairly heavy, and an annual average precipitation of 46.7 inches is reported.

At the present time, all of the valley floor and much of the surrounding mountainsides have been cleared of forests and utilized as pasture, since the chief occupation of the residents is cattle-raising. Due, perhaps, to this deforestation, and to the fact that most of our attention was devoted to the limestone caves, only one reptile, a dead *Natrix s. sipedon*, was seen during both visits. The number of amphibians encountered, however, was fairly large, and several species are of interest from a distributional standpoint. No claim of completeness is made for the present list, for we feel that future collections will reveal the presence of certain species conspicuous by their absence, such as *Pseudotriton r. ruber* (Latreille), *Rana s. sylvatica* LeConte, and others.

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1 The Geology and Mineral Resources of the Burkes Garden Quadrangle, Bull. Va. Geol. Surv., 60: xx, 1-299; 1944.

Localities within the Burkes Garden region at which collections were made are as follows:

1. *Cassell's Cave,* about two miles west of Burkes Garden Post Office, on the farm of Mr. D. M. Cassell. This cave, and several smaller, unnamed caverns in the immediate vicinity, occur in the Benbolt limestone. These caves are in an open pasture field at least a half-mile from the nearest forest of any extent. They are underlain by permanent streams, which were inaccessible to us.

2. *Lawson's Cave,* a large, stream-occupied solution channel, on the property of Mr. Mennis Lawson, about two miles northeast of Burkes Garden Post Office on County Route 666. Access to the cave is gained by a large sink-hole, across the bottom of which the stream flows. Progress on the up-stream member is obstructed by a duck-under, but we followed the down-stream passage for more than a quarter of a mile with little indication of possible impassibility. Residents believe that the stream emerges as Fish Spring, about a half-mile below the sink-hole. When we visited the cave on June 13, 1946, we found an abundant fauna, including, besides amphibians, large pallid fish (possibly cyprinids), crayfish (*Cambarus* sp.) and many small invertebrates.

3. *Beartown Mountain,* on the southwestern part of Garden Mountain, is 4705 feet above sea level, and is the highest peak in a very large area. Beartown is notable in that the southern slope off the top supports a considerable stand of red spruce, *Picea rubra* (DuRoi) Dietr. The northern side, facing Burkes Garden, is very steep, and the upper portion is thickly forested with such trees as *Acer pennsylvanicum* L., *Liriodendron tulipifera* L., and *Cercis canadensis* L., and various herbaceous plants including *Urtica dioica* L. and *Impatiens pallida* Nutt. The northern side has been cleared up to about the 4200 foot level. It is asserted by the residents that Beartown has approximately 200 rainy days a year, which may well be the case. An annual average of 150 rainy days is reported for the valley floor (data from Cooper, *op. cit.*). Our collections were made at a spring several hundred feet below the forest level; and from about 4500 feet to the top, particularly about dripping sandstone outcrops, where we searched for *Aneides.*

4. *Mill Gap.* This is the single outlet for the Burkes Garden drainage, and is on the western side of the valley. In addition to the stream, Virginia State Highway 78 also passes through Mill Gap, which is about 500 feet lower than the top of the ridge through which it cuts. At the bottom of the gap the vegetation is composed almost entirely of evergreen and ericaceous plants, including *Tsuga canadensis* (L.) Carr., *Rhododendron maximum* L., *Kalmia latifolia* L., and *Mitchella repens* L. Our collections were made on July 1, 1947, at an elevation of about 3000 feet.

About 70 specimens of amphibians were taken during our surveys, representing 13 species, and sound records are available for two others. The small number of specimens should not be considered a reflection of either scarcity or indifferent collecting. We did not collect large series, and fully twice as many specimens were seen as taken.

Appreciation is very gratefully expressed to the kind residents of Burkes Garden, particularly Mr. Dennis M. Cassell, for courtesies which have made our sojourns there especially pleasant. Dr. Doris M. Cochran has very generously made available specimens in the collection of the U. S. National Museum for comparisons with several species.

DESMOGNATHUS FUSCUS FUSCUS (Rafinesque)

Beartown Mountain, spring in open pasture, 2 specimens, U.S.N.M. Nos. 124430-31; Mill Gap, 2950 feet, 3 specimens, U.S.N.M. Nos. 124432-34.

The apparent scarcity of this species, notable because of its usual abundance, may be due to the lack of suitable habitat for it. Nowhere did we find aquatic plethodonts in any numbers.

DESMOGNATHUS MONTICOLA Dunn

Beartown Mountain, spring in open pasture, 2 specimens, U.S.N.M. Nos. 124435-36; Mill Gap, 2 specimens, U.S.N.M. Nos. 124437-38.

DESMOGNATHUS OCHROPHAEUS OCHROPHAEUS Cope

Cassell's Cave, 3100 feet, 8 specimens, U.S.N.M. Nos. 124444-51; Beartown Mountain, 5 specimens, U.S.N.M. Nos. 124439-43; Mill Gap, 3 specimens, U.S.N.M. Nos. 124452-54.

D. o. ochrophaeus may be regarded as the most abundant salamander of the region. We found at least twice as many as were taken, at each locality. At Cassell's Cave, specimens were found in wet moss and rocks where a portion of the ceiling had collapsed. On Beartown the species was common in the wet shady forest from about 4500 feet to the top, although none were found in the spruce forest proper, where conditions were considerably drier.

The Burkes Garden population is referred to the typical subspecies rather than to *D. o. carolinensis* Dunn on the basis of the dorsal pattern. Only three of the sixteen specimens at hand possess dorsal stripes whose edges approach the wavy condition peculiar to *carolinensis,* and it is interesting to note that these three were found on Beartown Mountain.

PLETHODON CINEREUS CINEREUS (Green)

Cassell's Cave, several immature specimens not taken; Mill Gap, 15 specimens, U.S.N.M. Nos. 124382-96. The National Museum also has 3 specimens, Nos. 109223-25, with no other locality than "Burkes Garden."

This species is probably more common than our collections indicate. The specimens from Mill Gap were found mostly in a rather dry pine-oak forest quite different from the other collection points in the Garden.

PLETHODON GLUTINOSUS GLUTINOSUS (Green)

Cassel's Cave, 1 adult found on June 13, 1946, U.S.N.M. No. 124509, and three immature specimens taken June 29-30, 1947, U.S.N.M. Nos. 124397-99; Mill Gap, 4 specimens, July 1, 1947, U.S.N.M. Nos. 124400-03.

At Cassell's Cave we found *glutinosus*, particularly small specimens, rather common at the caved-in portion in company with *D. o. ochrophaeus*. It was also found under large slabs of limestone near the cave entrance. At Mill Gap, the species was abundant, associated with *P. cinereus* in the rather dry oak and pine forest.

PLETHODON METCALFI Brimley

Beartown Mountain, 4500-4700 feet, 6 specimens, U.S.N.M. Nos. 124404-09; Mill Gap, 3000 feet, 2 specimens, U.S.N.M. Nos. 124410-11.

On Beartown this species was almost as common as *D. ochrophaeus*, and in fact, occurred on top in the spruce forest, where no specimens of the other form were found. *P. metcalfi* was found both in and under logs, and we found several beneath rocks at a dripping sandstone exposure where one would expect *Desmognathus* but not a *Plethodon*. At Mill Gap, which is, to the best of our knowledge, one of the lowest elevations at which *metcalfi* has been found, specimens were discovered under logs in the very damp hemlock-rhododendron association.

The discovery of *metcalfi* at Burkes Garden extends the known range of the species approximately forty miles northeast of the previous northernmost station—White Top Mountain. While the range extension is considerable in itself, we believe that the discovery of *P. metcalfi* in a mountain range quite apart from the others inhabited by the species is of more than casual interest. Clinch Mountain is widely separated from the Iron and Balsam Mountains by the rather low valley of the Holston River, and is the first large range outside the Blue Ridge Province (Southern Section) on which *metcalfi* has been found. The abundance of *metcalfi* at Burkes Garden, and its apparent independence of spruce forests, leads us to believe that future collections in southwestern Virginia will very likely result in the establishment of other interesting stations for the species.

GYRINOPHILUS PORPHYRITICUS INAGNOSCUS Mittleman

Lawson's Cave, 1 adult, June 13, 1946, U.S.N.M. No. 124508; Beartown, several larvae in spring, 4000 feet, not taken.

The single adult specimen found was discovered approximately a quarter of a mile inside Lawson's Cave, where we encountered it resting on the muddy bank of the stream. The larvae on Beartown Mountain were found under rocks in an ice-cold spring.

Our specimen is referred to Mittleman's *inagnoscus* following comparison with the type specimen of that subspecies in the National Museum and with specimens from elsewhere in the range of the species. This record constitutes a very considerable extension in the known range of *inagnoscus*, in addition to adding another form to the already large salamander fauna of Virginia. Further studies now being made by the junior author are expected to clarify the relationships and distribution of the gyrinophilids in Virginia.

EURYCEA BISLINEATA WILDERAE Dunn

Beartown, spring in open pasture, two young specimens, U.S.N.M. Nos. 124481-82; Mill Gap, 1 adult, U.S.N.M. No. 124483.

The specimen from Mill Gap was found under a rock in a dense rhododendron thicket several feet from the stream. The scarcity of *E. bislineata* is as surprising as the general rarity of *Desmognathus fuscus*.

We realize the inadvisability of assigning definite subspecific names to individual salamanders from intermediate areas such as Burkes Garden. However, the adult specimen at hand was compared with living specimens of *wilderae* from Mount Rogers, Virginia, and preserved material from North Carolina, and seems to be the same form. We therefore make the above identification with the realization that larger series from Burkes Garden may show that the population is at best an intergrading one. Verification of our record, however, will establish a new northern station for the subspecies, previously known in Virginia only from White Top Mountain (the type locality) and vicinity.

EURYCEA LONGICAUDA LONGICAUDA (Green)

Cassell's Cave, 2 adults, U.S.N.M. Nos. 124485, 124511

These specimens were found under fragments of rock at the cave entrance, in fairly dry soil. The absence of the species elsewhere in both Cassell's and Lawson's caves is noteworthy.

EURYCEA LUCIFUGA Rafinesque

Cassell's Cave, 1 adult, June 13, 1946, U.S.N.M. No. 124512, and 1 adult, June 29, 1947, U.S.N.M. 124486.

Both our specimens were found at night, and both at the cave entrance, walking about stiffly on the rocks. On the first occasion, there was a steady rainfall outside; on the second, the night was damp with a storm impending. We were surprised at the absence of this salamander further back in the cave, for the moisture and food supply seemed to be adequate.

The species has been previously reported from Cassell's Cave by Fowler,[2] on the basis of two specimens in the collection of the Academy of Natural Sciences of Philadelphia, Nos. 24744-45.

BUFO WOODHOUSII FOWLERI Hinckley

Cassell's Farm, heard June 13, 1946, and June 29-30, 1947.

HYLA CRUCIFER CRUCIFER Wied

Cassell's Cave, 1 specimen, U.S.N.M. No. 124510. Heard at Cassell's Farm, June 13, 1946, and June 29-30, 1947.

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2 Proc. Biol. Soc. Wash., 57: 31-32; 1944.

HYLA VERSICOLOR VERSICOLOR LeConte

Cassell's Farm, heard June 29-30, 1947.

We heard large numbers of this treefrog, but the animals were calling from trees and were inaccessible. It is of interest to note that two sorts of calls could be heard, recognizable by the senior author as corresponding to the two voice types previously reported by him in Virginia.[3] Burkes Garden is the first place in the state at which both kinds of calls have been heard, and its central location on the divide between the Ohio and Tennessee watersheds may have some affect on the disposition of the *versicolor* population. The mellow, prolonged trill was about twice as frequent as the distinctly different short and harsh note.

RANA CLAMITANS Latreille

Lawson's Cave, 2 specimens, U.S.N.M. Nos. 124506, 124513; Mill Gap, 1 large adult seen July 1, 1947.

The specimens taken in Lawson's Cave were found far downstream in the total darkness zone. Both this species and the following one were common in the cave, and we saw and heard quite a number. The incidence of ranids in Lawson's Cave is not surprising, for much of the drainage in that particular region is subterranean. The Mill Gap specimen was seen resting on a log in the dense rhododendron thickets, at least thirty feet from the stream.

RANA PALUSTRIS LeConte

Lawson's Cave, 1 specimen, U.S.N.M. No. 124507; Cassell's Cave, 1, collected on June 29, 1947 (not retained).

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3 Herpetologica, 3(4): 141-42; 1946.

A Partial Description of the Tadpole of Rana areolata circulosa and Notes on the Natural History of the Race

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In 1939 one of us (Philip Smith) while enrolled at Southern Illinois Normal University at Carbondale, intensively pursued a field study of *Rana areolata circulosa* under the direction of Dr. Fred R. Cagle. Actual work on it, concentrated in the vicinity of Herrin, Illinois, began in 1938, and was continued through 1940. Unforeseen developments prevented completion of the project, although in 1942 Cagle published excerpts from the data then accumulated.

The notes recorded during the study are available at the present time, in addition to a small portion of the preserved materials. Among the latter are five mature and transforming tadpoles, especially valuable since the larval stage of this species has never been described. With our description of the tadpoles, we include certain apparently novel materials from Smith's notes.

Unfortunately all the small jars containing stomach contents and tadpoles at various stages of development were completely dry when reexamined in the summer of 1947 after a few years of storage. The material would have been a total loss had it not been possible to restore it partially by the technique described recently by Van Cleave and Ross (1947). In fact Dr. Van Cleave kindly treated the dried specimens for us. The tadpoles were rendered flexible enough to permit manipulation, although they remained shrunken in appearance. The mouth disks appear normal, but body proportions are unquestionably distorted; accordingly, while the description of the mouthparts may be considered more or less accurate, the measurements are undoubtedly subject to correction on the basis of fresh material.

Field Observations

A summary of part of the field observations, as stated previously, appeared in a report by Cagle (*loc. cit.*). A few additional notes follow.

Emergence was observed as early as the third week in February (1938). Not infrequently specimens were found in shallow water at temperatures so low that activity was greatly inhibited and no sexual expression whatever was evident. In 1939, breeding activity extended over a period of some 35 days. In 1938, almost exactly the same period was involved, although it began later (about March 12). During the first 5 or 6 days, the males appeared to predominate at the breeding congresses, and after then most frogs migrating to the breeding pools were observed to be females. The females apparently left

the pools shortly after ovipositing, since very few were observed about the pools after 12 days from the first evidence of breeding. For a time after all specimens had left the ponds, males could be heard calling occasionally, under favorable conditions, from their holes in the fields. As early as April 19, 1938, specimens were being plowed up in fields at depths of about 6 inches.

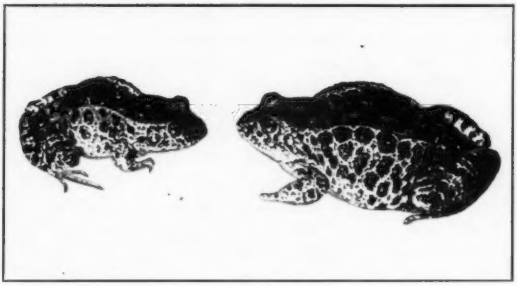

Fig. 1.—*Rana areolata circulosa* from Herrin, Illinois. Both specimens are females.

In six egg masses the minimum count of eggs was 3192, and the maximum 6807.

Air and water temperatures of about 10° C. appear to be the critical optimum for *R. areolata*. Breeding activity does not begin until they reach about 8° C., and is not active until about 12° C. When well under way, the breeding activity lessens markedly by reduction of temperatures to 10° C., and virtually ceases at 6° C. or less.

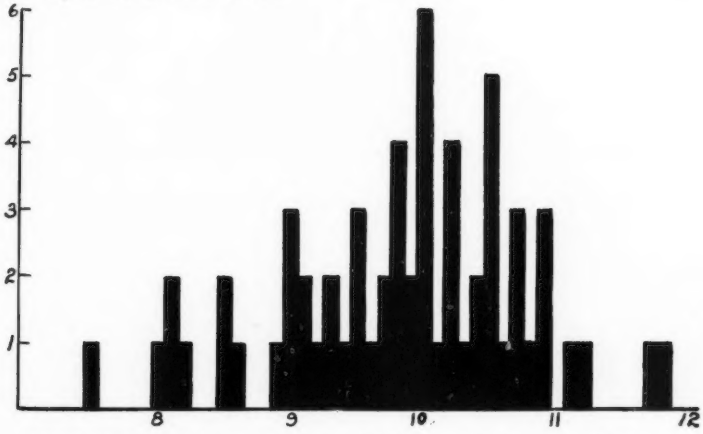

Fig. 2.—Histogram showing frequency distribution of snout-vent lengths by millimeters in males. Lengths are plotted by millimeters on the abcissa (the figures refer to centimeters), number of individuals on the ordinate.

This is one of the few Ranas of the United States, apparently, whose breeding activity is closely correlated with rainfall. Warm weather (exceeding 10° C.) in spring is insufficient alone to stimulate breeding activity; a certain amount of rainfall is required in addition. Records available do not indicate the optimum quantity or violence of the rains.

A series of 432 specimens was collected on two successive nights and sexed, measured (snout to vent) and weighed. The accompanying figures (Figs. 2-5) summarize these data. These tabulations reveal presence at the choruses of surprisingly small, presumably sexually mature individuals; 6.4 cm. snout to vent (0.5 ounce) was the minimum recorded in males, 7.5 cm. (2 ounces) in females. The largest recorded was 11.7 cm. in a male (6 oz.) and 11.8 cm. in a female (6 oz.). A difference between the sexes is indicated for the minimum as well as the average (length, ♂ 9.3, ♀ 9.8; weight, ♂ 2.6, ♀ 3.4) breeding sizes, but the maximum sizes and weights appear little different. In both sexes the weight becomes disproportionately greater as the length increases; the curve is almost identical in males and females.

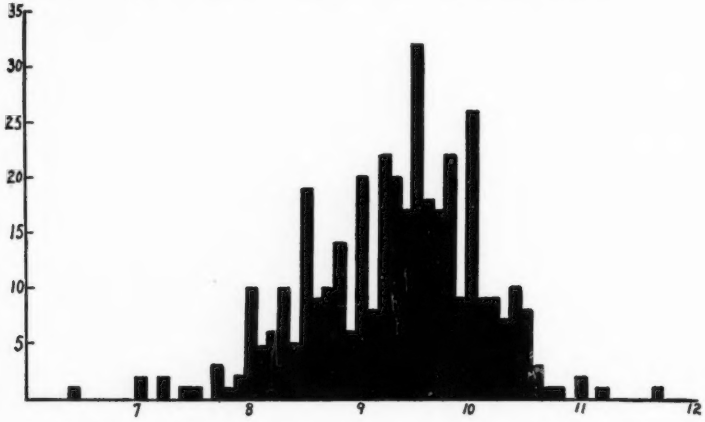

Fig. 3.—Frequency distribution of snout-vent lengths in females plotted as in Fig. 2.

The series of 143 collected on the first night (March 10, 1939) was selected for calling males, but the group collected the following night (289) was assembled indiscriminately so far as sex and call were concerned. Despite that fact the sex ratio strongly favors the male (371:61 or 6.08:1). We suspect that, although no conscious selection was exerted in accumulation of the second series, behavior of the frogs effected a selection of more males than females.

Stomach contents of about 18 specimens taken in the breeding season of 1941 include small numbers of beetles and beetle larvae (carabids, tenebrionids), millipedes, centipedes, and small crayfish.

EGGS

The details of egg structure of *Rana areolata* in eastern Kansas have been described by Smith (1934:479, pl. 12, fig. 7), who also recorded observations on the egg masses as a whole. Cagle (1942:182) records further observations (from data furnished by Philip E. Smith) on the egg masses (wrongly assigned to *R. a. areolata* by Livezey and Wright [1947:208]; the eggs of the latter race are as yet not recorded). Observations on egg masses in Kansas and Illinois reveal no discrepancies, but the details of egg structure appear to differ markedly. In Kansas, eggs were measured with vitelli 2.46 to 2.5 mm.

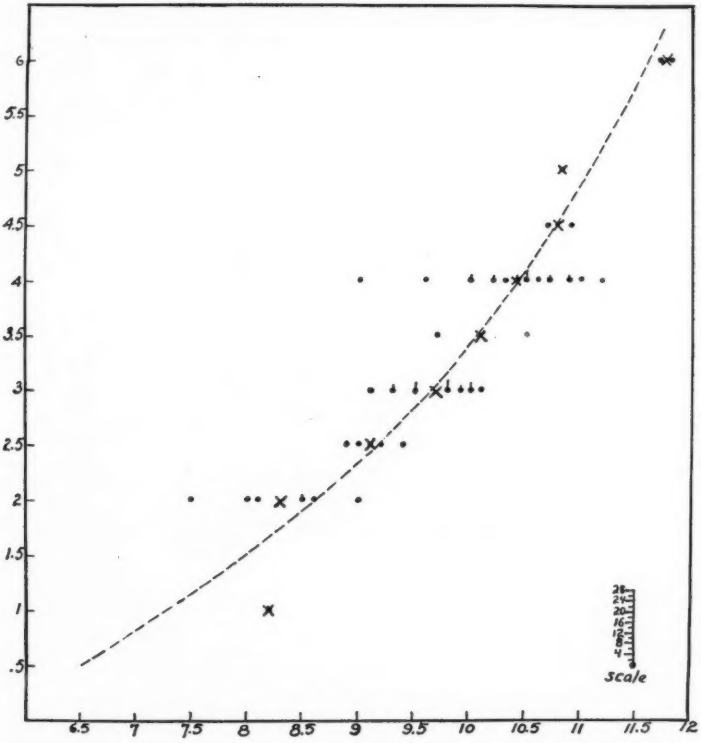

Fig. 4.—Graph showing relationships between snout-vent lengths (in tenths of centimeters on the abcissa) and weights (in half ounces on the ordinate) in males. Number of individuals possessing a given combination is indicated by a vertical line from the appropriate point; the scale for number of individuals is indicated in the lower right corner of the graph. Average lengths of individuals with a given weight are indicated by an X. The portion of the curve provided by significant points is indicated by a solid line; the remainder, obviously hypothetical, is indicated by a dashed line.

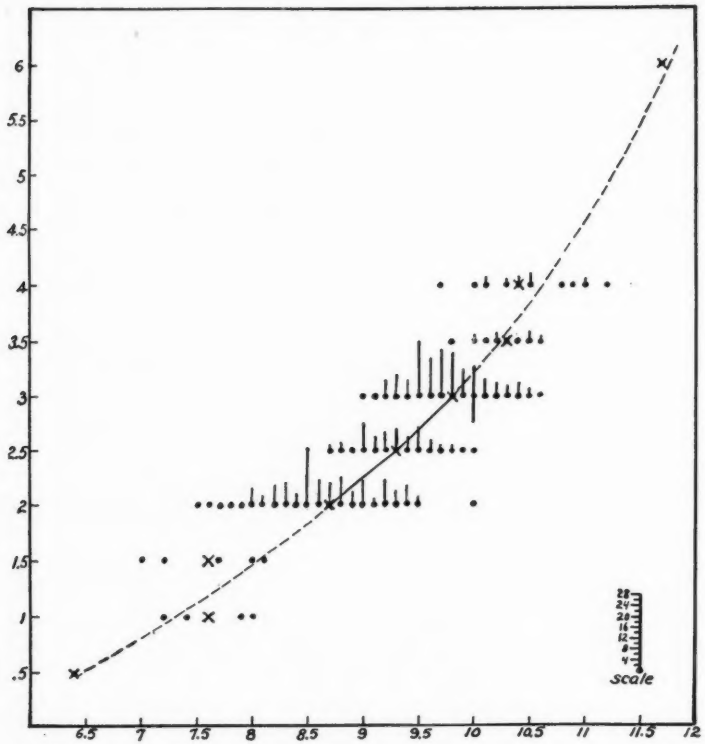

Fig. 5.—Weight and snout-vent relationships in females, plotted as in Fig. 4.

in diameter, inner envelopes about 3.15 mm., and outer envelopes about 4.5 to 5.0 mm. in diameter. Illinois eggs have vitelli 1.91 to 2.18 mm. in diameter (average 2.05 in 12), inner envelopes 2.3 to 3.1 mm. in diameter (average 2.53 mm. in 7), outer envelopes 3.9 to 4.3 mm. in diameter (average 4.03 in 6). The Illinois eggs had been preserved in formalin for 7½ years prior to measurement and study, while the Kansas eggs were measured when fresh. The discrepancies thus may well not be inherent. Furthermore, actual measurement of the Illinois eggs was difficult to perform accurately since the envelopes and even the vitelli were distorted.

The most reliable difference between the eggs of *R. pipiens* and *R. areolata* appears to be in size of the vitellus, which is almost invariably larger in the latter species.

TADPOLES

General Appearance.—A medium-sized tadpole, maximum total length before metamorphosis about 65 mm.; tail tip somewhat attenuated and elongate, sharply pointed; dorsal crest extended forward to the level of the rear edge of the spiracle; latter sinistral, on the lateral axis, directed posteriorly and somewhat upward. Tail fins equally pigmented above and below; spots on tail small (about 1 mm. in diameter) diffuse, scattered irregularly at intervals about equal to their own diameter. Pattern of body indecipherable.

Mouthparts.—Labial teeth in $^2/_3$ rows. Entire disk surrounded by a fringe of papillae except a median zone of the upper labium but little shorter than the outer row of teeth; papillary fringe indented laterally; inner row of teeth in upper labium divided medially by a space about $^3/_7$ the length of either half. Tooth rows in lower labium subequal in length (the outer slightly the shortest) but little shorter than the outer row of the upper labium.

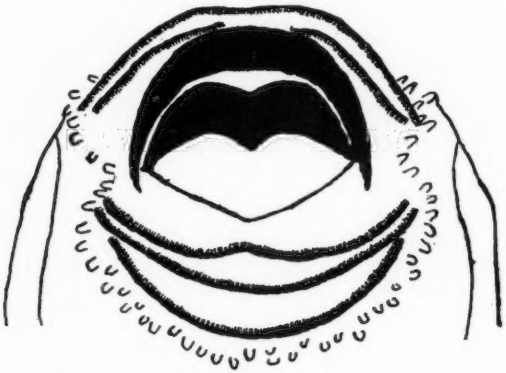

Fig. 6.—Mouth disk of *Rana areolata circulosa*, ×10.

Measurements.—The largest tadpole available possesses the following measurements: total length, 65 mm.; length of body, 23 mm.; width of body, 15 mm.; depth of body, 12 mm.; tail, 42 mm.; tail depth, 15 mm.; maximum depth of tail musculature, 6 mm,; spiracle to snout, 12 mm.; spiracle to vent, 11 mm.; spiracle to rear edge of eye, 5.5 mm.; eye to snout, 5 mm.; mouth disk width, 3 mm. The specimen figured herewith measures 38 mm. in total length, the body 18 mm.

Comparisons.—Condition of the body of these tadpoles is such that no comparisons with other species are warranted. The mouthparts, however, furnish details sufficiently unaltered that differences observed may be considered reliable.

The chief distinction between the mouthparts of this and other species

appears to be the relatively very narrow interruption between the two halves of the inner row of teeth of the upper labium. In no other *Rana* of the United States with a labial formula of $^2/_3$ is that space less than the length of either half of the tooth row; *R. sphenocephala* represents perhaps the closest approach, with a reduction of the space to $^1/_2$ of the length of either half of the tooth row. All other species are readily eliminated on the basis of this character and the formula of $^2/_3$ labial teeth.

Among the three mature tadpoles available, one possesses a median space in the second upper row about $^4/_7$ the length of either toothed half; in both other specimens the space is much shorter. However, in two transforming tadpoles with well-developed hind legs but no external evidence of forelegs, the median space is even longer than either half of row 2. We attribute the condidition in the latter two to the labial degeneration that accompanies metamorphosis, inasmuch as the upper labium in both specimens is reduced in size.

It may perhaps safely be stated then that the median space in the second labial row of *R. areolata circulosa* varies under normal conditions from about $^2/_7$ to $^4/_7$, and is usually less than $^1/_2$, the length of either toothed half.

From *R. sphenocephala*, no doubt, many specimens could be distinguished by the very short median space, but fortunately another character apparently will readily distinguish all specimens: the relative length of the fifth (lower) row of teeth and the mandible. They are subequal or the row of teeth is longer in *R. areolata circulosa*, while in *R. sphenocephala* the row is always shorter than ($^1/_6$ to $^1/_5$) the horny beak.

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The Vertebrate Fauna of the Huron Mountains, Michigan*

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Introduction

The Huron Mountains lie immediately south of Lake Superior in the extreme northwestern part of Marquette County, some forty miles distant from the city of Marquette, in the Upper Peninsula of Michigan. This region represents one of the most extensive and best preserved tracts of primeval forest in the state. A portion of the area is controlled by a private organization, the Huron Mountain Club, which has owned property here since 1889. Its holdings now include approximately fifteen thousand acres which embrace the principal topographic features of the region.

It was my good fortune, in the autumn of 1939, to undertake a wildlife survey for the Huron Mountain Club. Attention was focused on a large block of land (41,050 acres, enclosed by the heavy line in Figure 1) which included most of the mountains, lakes, and major streams of the country, as well as samples of all the chief northern forest types. This work was conducted from October 1, 1939 until August 1, 1942. During this time approximately nineteen months in all and more than one year continuously were spent in the field.

An inventory of the recent vertebrates of the Huron Mountains was prepared from trapping records and observations in the field, supplemented by accounts in the literature and by the reports of old residents of the area and early members of the Club. Attention was paid chiefly to the mammals; a special study of small mammal populations on eight selected plots is reported elsewhere (Manville, in press).

Acknowledgements

Many individuals have assisted in various ways during this study. To Laird Bell I am grateful for the financial support which made it possible. From Carter H. Harrison, Daniel L. Hebard, and Oliver Morris I have learned much of wildlife conditions in

*A portion of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan.

the region during the decade before 1900. Many records of later years have been generously supplied by Bayard H. Christy, Stephen S. Gregory, Jr., William P. Harris, Jr., S. Morris Pell, H. Emerson Tuttle, and Josselyn Van Tyne. Throughout the study I received the hearty co-operation of the entire personnel of the Club; in this connection I wish especially to mention the late Herbert E. Perkins, Club manager, and David M. Nason, Club warden, who were of constant and invaluable service by reason of their extensive experience and thorough acquaintance with local conditions. The Michigan Conservation Department kindly supplied records of predatory animal hunters in the Huron Mountain region. H. B. Cowdrick furnished meteorological data for the city of Marquette. My work was directed by William H. Burt, to whom I am grateful for his interest and guidance at all times; I am further indebted to him, as well as to Reeve M. Bailey, Lee R. Dice, Frederick M. Gaige, Norman A. Hartweg, and Josselyn Van Tyne, for critically reading the manuscript, in whole or in part. Others who have aided in this study are indicated in the text.

Nature of the Country

The Huron Mountains are an isolated range of granitic knobs and ridges, the highest of which (Ives Hill) rises to 1632 feet above mean sea level or 1030 feet above the level of Lake Superior. Huron Mountain, Ives Mountain, Mount Homer, Mount Ida, and Mount Benison reach nearly this elevation. There is a fringing belt of comparatively level country, from approximately one to four miles wide, lying between Lake Superior and the base of these mountains. During the Pleistocene the region was completely inundated by

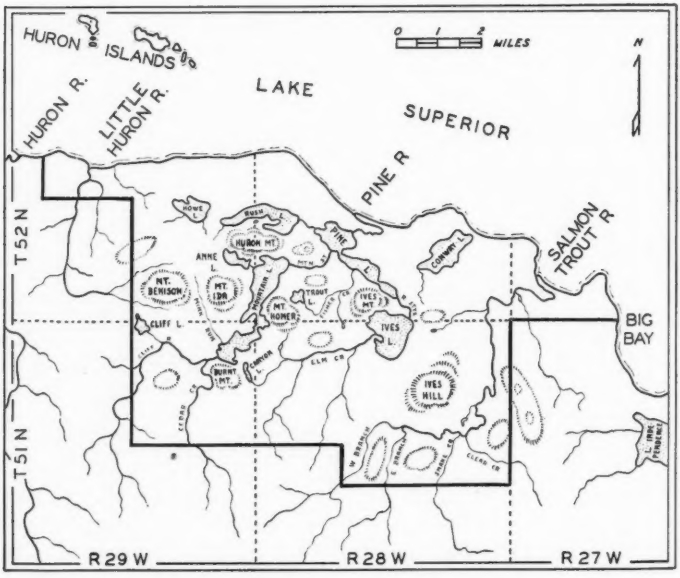

Fig. 1.—The Huron Mountain Region.

successive ice sheets. Glacial Lake Algonquin stood about three hundred feet above the present level of Lake Superior; the later Lake Nipissing was thirty feet above the present Lake Superior (Leverett, 1929). As these waters receded, scattered lakes were left among the hills. There are today ten chief inland lakes, ranging in area from ten acres (Canyon Lake) to 775 acres (Mountain Lake). Drainage throughout the area is into Lake Superior, mainly by the Little Huron, Pine, and Salmon Trout rivers and their tributary waters.

This region lies in a zone of transition between the northern coniferous forests and the eastern deciduous forests. Dice (1943) includes the area in the Canadian biotic province. Nichols (1934) regarded it as "the finest if not the only unmodified tract of pine-containing climax forest in the Upper Peninsula of Michigan." Most of the lands can still be described as virgin stands. Scattered throughout the property are many old patriarchs—white pines as much as five feet in diameter at breast height, sugar maples and red oaks which must be centuries old.

The chief changes in the forests since the arrival of white man are those wrought by logging and fires. As early as 1885 small logging crews invaded the region, cutting white pine almost exclusively. This valuable tree was taken wherever proximity to water, for the spring drives, made the operation feasible. At one time over a million feet of timber were floated down the Salmon Trout River in one day. The available pine was nearly exhausted by about 1902, although there still remain many isolated trees that it was impractical to cut. The era of hardwood lumbering was in vogue in the Huron Mountains from 1919 to 1942. Sugar maple, yellow birch, and basswood were the trees of greatest value, but the method of "clean cutting" was to remove all trees regardless of other considerations. This era witnessed cutting operations chiefly in the area north and west of Rush and Howe Lakes, and east of Conway and Ives Lakes. In recent years there has been a growing tendency toward "selective cutting," whereby but a portion of the merchantable trees are removed.

During the days of small logging camps there were occasional fires, none of which were extensive. These were chiefly along the Salmon Trout drainage. Six other known fires, in scattered localities, ravaged Huron Mountain lands between 1890 and 1934. Most of these fires were limited to forty acres or so in extent. The Ives Lake Farm (some 275 acres) and the Club Farm (10 acres) represent the major cleared lands in the region. Approximately twenty miles of narrow dirt roads and woodroads are maintained on the property.

The area surveyed was cover mapped in a general way. Terminology of the different types is adapted largely from Cunningham (1939). The principal cover types on these lands, as of 1941, are shown in the following tabulation:

Northern hardwoods—upland forest of sugar maple, yellow birch, basswood, elm, hemlock, in pure or mixed stands; virgin forest ..... 11,600 acres

Mixed hardwoods and softwoods—white spruce, balsam fir, white cedar, hemlock, aspen and white birch on uplands,

with mixture of elm, red maple, yellow birch, balm-of-Gilead, and black ash on lowlands; virgin forest ..... 9,300 acres

Mixed conifers—upland and lowland forest, predominantly hemlock, with some white or Norway pine and scattered sugar maples; white spruce, balsam fir, and white cedar along shores; largely virgin forest ..... 6,980 acres

Pioneer hardwoods—upland and lowland areas of aspen, white birch, pin cherry, striped maple, sugar maple saplings; lands deforested by fire or clean cutting ..... 4,700 acres

Swamps and marshes—lowland areas of willow, leatherleaf, sweet gale, alder; beaver flowages, bogs ..... 1,500 acres

Pine—upland and lowland areas of jack pine, Norway pine, white pine, in pure or mixed stands in various stages of the succession ..... 1,450 acres

Conifer swamps—lowland areas of white cedar, black spruce, tamarack, or balsam fir in deep peat swamps; some hemlock and black ash ..... 1,420 acres

Rocky outcrops—uplands, mostly bare, some burned; scattered pines and pioneer hardwoods ..... 1,000 acres

Cleared lands—meadows, pastures, cultivation ..... 300 acres

Inland lakes and ponds ..... 2,800 acres

Total acreage ..... 41,050 acres

Weather Conditions

Daily records were kept of maximum and minimum temperatures and of general weather conditions in the Huron Mountains for one year. Comparison with the records of the U. S. Weather Bureau station at Marquette for the same period shows conditions to be essentially the same at the two places, with a tendency for the temperatures in the Huron Mountains to range a few degrees higher than those at Marquette. For most purposes temperature data at Marquette are directly applicable to the Huron Mountains, at least to that portion along the Lake Superior shore. Records from the Marquette Weather Bureau station since 1874 show the following annual *normals:* precipitation, 32.54 inches; unmelted snow, 114.2 inches; per cent of possible sunshine, 45; relative humidity, 74 per cent.

A climatic summary for the city of Marquette, compiled by Wills (1941) and based on records of forty years, discloses the following figures: average January temperature, 17.4° F.; average July temperature, 65.3° ; maximum temperature, 108.0°; minimum temperature, –27.0°; last killing frost in spring, May 9; first killing frost in fall, October 14; length of growing season, 158 days. Wills further described the equalizing effect of Lake Superior on the climate of its south shore; the prevailing northwest wind tempers the extremes of temperature, lengthening the growing season and producing a semimarine

type of weather with less pronounced fluctuations in temperature than are found further inland. This effect of proximity to Lake Superior is apparent in the Huron Mountains. Snow may fall several weeks earlier a few miles inland than it does near the shore; also snow depths are greater. On March 7, 1940, for instance, the snow was 17 inches deep at the Five Forks, two miles south of the Lake Superior shore; at a point two and one-half miles further south, but not more than 100 feet higher, the snow was 34 inches deep at the time.

Annotated List of Vertebrates

The following notes apply chiefly to the area in the Huron Mountains included in this survey. However, all forms are listed of which Marquette County specimens have been collected, which have been positively identified by competent observers in the field, or of which there are in the literature accounts referable to Marquette County—as any of these forms may reasonably be expected to occur in the Huron Mountains. Included are several records from the Yellow Dog Plains, about ten miles south of Lake Superior, and from Marquette County generally. Specimens preserved are those of the writer, and are deposited in the collections of the Museum of Zoology at the University of Michigan, Ann Arbor.

No work was done on the fishes during the present study. For the sake of completeness a list of forms occurring in the Huron Mountains is included, taken from Hubbs and Lagler (1941) and from Smith (1941). Nomenclature of the amphibians and reptiles follows Stejneger and Barbour (1939); that of birds is after Van Tyne (1938); and the nomenclature of mammals is that adopted by Burt (1946).

The chief published references on the amphibians and reptiles of the area are those by Ruthven (1906) and by Ruthven, Thompson and Gaige (1928). Papers on the local birds have been published by Christy (1925*a*, *b*, 1929*b*, 1930, 1942), Gregory (1929), Manville (1941, 1948), Tuttle (1919), and Van Tyne (1934, 1937). For the most part the birds are classed as follows: pemanent residents; summer residents; winter visitants; and transients, i.e. migrant in spring or fall, or both. Some birds, irregular or sporadic in appearance, are extra-limital invaders which may in time become established. Frequency is indicated as abundant, common, uncommon, or rare, based on the author's observations. Where records exist, breeding status is indicated. The subspecific identity of the house wren, veery and song sparrow cannot be determined until specimens are collected and critically examined.

The present list includes 325 forms, forty-three more than appeared in *The Book of Huron Mountain* (Christy, 1929*a*). The following numbers of species and subspecies are represented here:

Fishes	47
Amphibians	13
Reptiles	9
Birds	206
Mammals	50

Of the 325 forms, nine are now considered to be extirpated in the Huron

Mountains. These include one bird (passenger pigeon) and eight mammals (marten, fisher, wolverine, Canada lynx, cougar, moose, caribou, and the introduced house rat). Several other forms are now extremely scarce. Of those now extant, the American smelt and brown trout, the starling and English sparrow, and the coyote, domestic dog and house cat (existing in a feral state), house mouse, and cottontail have been introduced through the agency of man, mostly since the turn of the century.

The list of species follows.

FISHES

Ichthyomyzon fossor Reighard and Cummins. Northern Brook Lamprey.
Acipenser fulvescens Rafinesque. Rock Sturgeon.
Osmerus mordax (Mitchill). American Smelt.
Leucichthys artedi artedi (Le Sueur). Lake Herring.
Leucichthys artedi huronicus Koelz. Rush Lake Cisco.
Leucichthys artedi annensis Koelz. Lake Ann Cisco.
Leucichthys artedi clemensi Koelz. Nipigon Cisco.
Leucichthys artedi russeli Koelz. Pine Lake Cisco.
Leucichthys hoyi (Gill). Great Lakes Bloater.
Leucichthys hubbsi Koelz. Ives Lake Cisco.
Coregonus clupeaformis clupeaformis (Mitchill). Great Lakes Whitefish.
Prosopium cylindraceum quadrilaterale (Richardson). Round Whitefish.
Salvelinus fontinalis fontinalis (Mitchill). Common Brook Trout.
Cristivomer namaycush namaycush (Walbaum). Lake Trout.
Cristivomer namaycush huronicus Hubbs. Rush Lake Trout.
Salmo trutta fario Linnaeus. Brown Trout.
Esox lucius Linnaeus. Northern Pike.
Catostomus catostomus catostomus (Forster). Eastern Sturgeon Sucker.
Catostomus commersonnii commersonnii (Lacépède). Eastern White Sucker.
Couesius plumbeus plumbeus (Agassiz). Lake Northern Chub.
Rhinichthys cataractae cataractae (Valenciennes). Great Lakes Longnose Dace.
Pfrille neogaea (Cope). Finescale Dace.
Chrosomus eos Cope. Northern Redbelly Dace.
Notemigonus crysoleucas auratus (Rafinesque). Western Golden Shiner.
Notropis cornutus frontalis (Agassiz). Northern Common Shiner.
Notropis hudsonius hudsonius (Clinton). Northern Spottail Shiner.
Notropis heterodon (Cope). Blackchin Shiner.
Notropis heterolepis heterolepis Eigemann and Eigemann. Northern Blacknose Shiner.
Notropis volucellus volucellus (Cope). Northern Mimic Shiner.
Hyborhynchus notatus (Rafinesque). Bluntnose Minnow.
Pimephales promelas promelas Rafinesque. Flathead Minnow.
Lota lota maculosa (Le Sueur). Eastern Burbot.
Percopsis omiscomaycus (Walbaum). Troutperch.
Stizostedion vitreum vitreum (Mitchill). Yellow Walleye.
Perca flavescens (Mitchill). Yellow Perch.
Percina caprodes semifasciata (De Kay). Northern Logperch.

Boleosoma nigrum nigrum (Rafinesque). Central Johnny Darter.
Poecilichthys exilis (Girard). Iowa Darter.
Micropterus dolomieu dolomieu Lacépède. Northern Smallmouth Bass.
Lepomis macrochirus macrochirus Rafinesque. Common Bluegill.
Ambloplites rupestris rupestris (Rafinesque). Northern Rock Bass.
Cottus bairdii bairdii Girard. Northern Muddler.
Cottus bairdii kumlieni (Hoy). Great Lakes Muddler.
Cottus cognatus Richardson. Slimy Muddler
Cottus ricei (Nelson). Spoonhead Muddler.
Eucalia inconstans (Kirtland). Brook Stickleback.
Pungitius pungitius (Linnaeus). Ninespine Stickleback.

AMPHIBIANS

Triturus viridescens viridescens (Rafinesque). Newt or Red Eft.—Uncommon in the Huron Mountains. Two specimens preserved.
Ambystoma jeffersonianum (Green). Jefferson's Salamander.—Rare.
Ambystoma maculatum (Shaw). Spotted Salamander.—Rare.
Plethodon cinereus (Green). Red-backed Salamander.—Common. Six specimens preserved.
Bufo americanus americanus (Holbrook). American Toad.—Common. Two specimens preserved.
Hyla crucifer Wied. Spring Peeper.—Abundant. Five specimens preserved.
Hyla versicolor versicolor (Le Conte). Common Tree-toad.—Uncommon in the Huron Mountains. Three specimens preserved.
Rana catesbeiana Shaw. Bullfrog.—Rare.
Rana clamitans Latreille. Green Frog.—Common. Four specimens preserved.
Rana palustris Le Conte. Pickerel Frog.—Uncommon. One specimen preserved.
Rana pipiens Schreber. Leopard Frog.—Abundant. Three specimens preserved.
Rana septentrionalis Baird. Mink Frog.—Uncommon. Two specimens preserved.
Rana sylvatica cantabrigensis Baird. Wood Frog.—Common. Three specimens preserved.

REPTILES

Eumeces fasciatus (Linnaeus). Blue-tailed Skink.—Two specimens preserved.
Diadophis punctatus edwardsii (Merrem). Ring-necked Snake.—Uncommon. Five specimens preserved.
Opheodrys vernalis (Harlan). Green Snake).—Rare.
Elaphe vulpina vulpina (Baird and Girard). Pine or Fox Snake.—Uncommon. Two specimens preserved.
Storeria occipitomaculata (Storer). Red-bellied Snake.—Uncommon. Two specimens preserved.
Thamnophis sirtalis sirtalis (Linnaeus). Garter Snake.—Common. Three specimens preserved.
Chelydra serpentina (Linnaeus). Snapping Turtle.—Common.
Emys blandingii (Holbrook). Blanding's Turtle.—Rare.
Chrysemys picta bellii (Gray). Painted Turtle.—Common. Five specimens preserved.

BIRDS

Gavia immer elasson Bishop. Lesser Loon.—Common summer resident, May 12 to October 31. Breeds.

Gavia stellata (Pontoppidan). Red-throated Loon.—Rare.

Colymbus grisegena holboelli (Reinhardt). Holboell's Grebe.—Rare.

Colymbus auritus Linnaeus. Horned Grebe.—Uncommon transient, September 13 to December 10.

Podilymbus podiceps podiceps (Linnaeus). Pied-billed Grebe.—Uncommon summer resident, April 10 to October 21. Breeds.

Phalacrocorax auritus auritus (Lesson). Double-crested Cormorant.—Summer resident, as late as October 14. Breeds.

Ardea herodias herodias Linnaeus. Great Blue Heron.—Common summer resident, April 15 to October 16. Breeds.

Botaurus lentiginosus lentiginosus (Montagu). American Bittern.—Uncommon summer resident, May 29 to October 11.

Ixobrychus exilis exilis (Gmelin). Eastern Least Bittern.—Rare.

Branta canadensis canadensis (Linnaeus). Canada Goose.—Common transient, April and October.

Chen caerulescens (Linnaeus). Blue Goose.—Rare.

Anas platyrhynchos platyrhynchos Linnaeus. Mallard.—Uncommon transient, October 1 to November 10.

Anas rubripes Brewster. Black Duck.—Common summer resident, April 20 to November 18. Breeds.

Anas acuta tzitzihoa Vieillot. American Pintail.—Rare.

Anas crecca carolinensis Gmelin. Green-winged Teal.—Rare.

Anas discors Linnaeus. Blue-winged Teal.—Rare summer resident, June 15 to October 7. Breeds.

Anas strepera Linnaeus. Gadwall.—Rare

Mareca americana (Gmelin). Baldpate.—Rare.

Aix sponsa (Linnaeus). Wood Duck.—Rare summer resident, May 29 to October. Breeds.

Aythya americana (Eyton). Redhead.—Rare fall transient.

Aythya collaris (Donovan). Ring-necked Duck.—Uncommon transient.

Aythya valisineria (Wilson). Canvas-back.—Rare fall transient.

Aythya affinis (Eyton). Lesser Scaup Duck.—Common transient, May 7 to June 5 and September 30 to October 31.

Bucephala clangula americana (Bonaparte). American Golden-eye.—Common winter visitant, November 10 to April 24.

Bucephala albeola (Linnaeus). Buffle-head.—Winter visitant, October 17 to January 19, and probably later.

Clangula hyemalis (Linnaeus). Old-squaw.—Rare.

Oidemia nigra americana Swainson. American Scoter.—Rare.

Melanitta fusca deglandi (Bonaparte). White-winged Scoter.—Rare.

Oxyura jamaicensis rubida (Wilson). Ruddy Duck.—Rare.

Lophodytes cucullatus (Linnaeus). Hooded Merganser.—Rare summer resident, June 30 to October 30. Breeds.

Mergus merganser americanus Cassin. American Merganser.—Common sum-

mer resident, April 22 to December 15. Breeds. One specimen preserved.

Mergus serrator Linnaeus. Red-breasted Merganser.—Uncommon summer resident, June 15 to October 9.

Accipiter gentilis atricapillus (Wilson). Eastern Goshawk.—Rare summer resident, June 26 to October 23. Breeds.

Accipiter striatus velox (Wilson). Sharp-shinned Hawk.—Uncommon summer resident, May 29 to October 14.

Accipiter cooperi (Bonaparte). Cooper's Hawk.—Uncommon summer resident, May 24 to September 23.

Buteo jamaicensis borealis (Gmelin). Eastern Red-tailed Hawk.—Common summer resident, April 30 to October 4.

Buteo lineatus lineatus (Gmelin). Northern Red-shouldered Hawk.—Rare.

Buteo lagopus sancti-johannis (Gmelin). American Rough-legged Hawk.—Fall transient.

Buteo platypterus platypterus (Vieillot). Broad-winged Hawk.—Uncommon summer resident, May 13 to October 12.

Haliaeetus leucocephalus washingtoniensis (Audubon). Northern Bald Eagle.—Uncommon summer resident, April 2 until November. Breeds.

Circus cyaneus hudsonius (Linnaeus). Marsh Hawk.—Uncommon summer resident, May 22 until October 9.

Pandion haliaetus carolinensis (Gmelin). Osprey.—Rare summer resident, May 21 to October 9. Breeds.

Falco peregrinus anatum Bonaparte. Duck Hawk.—Rare summer resident, June 11 to September 24. Breeds.

Falco columbarius columbarius Linnaeus. Eastern Pigeon Hawk.—Uncommon summer resident, May 22 to September 30. Breeds.

Falco sparverius sparverius Linnaeus. Eastern Sparrow Hawk.—Uncommon summer resident, May 11 to September 9.

Canachites canadensis canace (Linnaeus). Canada Spruce Grouse.—Rare permanent resident.

Bonasa umbellus togata (Linnaeus). Canada Ruffed Grouse.—Common permanent resident. Breeds.

Tympanuchus cupido pinnatus (Brewster). Greater Prairie Chicken.—A recent addition to the Huron Mountain fauna.

Pedioecetes phasianellus campestris Ridgway. Prairie Sharp-tailed Grouse.—Rare permanent resident. A recent arrival in the Huron Mountains.

Rallus limicola limicola Vieillot. Virginia Rail.—Rare summer resident, May 30 to September 9.

Porzana carolina (Linnaeus). Sora.—Rare summer resident, June 15 to September 30. One specimen preserved.

Fulica americana americana Gmelin. American Coot.—Common fall transient, September 4 to October 16.

Squatorola squatorola (Linnaeus). Black-bellied Plover.—Rare transient, September 12 to October 7.

Pluvialis dominica dominica (P. L. S. Muller). Golden Plover.—Rare.

Charadrius hiaticula semipalmatus Bonaparte. Semipalmated Plover.—Common transient, August 7 to September 24.

Charadrius vociferus vociferus Linnaeus. Killdeer.—Rare summer resident, May 28 to August 27.
Bartramia longicauda (Bechstein). Upland Plover.—Rare transient.
Tringa flavipes (Gmelin). Lesser Yellow-legs.—Rare transient.
Tringa melanoleuca (Gmelin). Greater Yellow-legs.—Rare transient.
Tringa solitaria solitaria Wilson. Eastern Solitary Sandpiper.—Common transient, May 17 to 29 and July 21 to October 7.
Actitis macularia (Linnaeus). Spotted Sandpiper.—Common summer resident, May 15 to September 19. Breeds.
Arenaria interpres morinella (Linnaeus). Ruddy Turnstone.—Uncommon transient, August 27 to October 5.
Capella delicata (Ord). Wilson Snipe.—Uncommon summer resident, May 13 to October 16.
Philohela minor (Gmelin). Woodcock.—Uncommon summer resident, April 19 to October 19.
Crocethia alba (Pallas). Sanderling.—Uncommon transient, August 8 to September 28.
Ereunetes pusillus (Linnaeus). Semipalmated Sandpiper.—Uncommon transient, late August.
Erolia minutilla (Vieillot). Least Sandpiper.—Uncommon transient, May 16 to 31 and August 24 to September 28.
Erolia melanotos (Vieillot). Pectoral Sandpiper.—Rare transient.
Erolia alpina sakhalina (Vieillot). Red-backed Sandpiper.—Rare transient.
Steganopus tricolor Vieillot. Wilson's Phalarope.—Rare.
Stercorarius pomarinus (Temminck). Pomarine Jaegar.—Rare.
Larus delawarensis Ord. Ring-billed Gull.—Uncommon transient, September 12 to October 12.
Larus argentatus smithsonianus Coues. Herring Gull.—Common permanent resident, less frequent in winter. Breeds.
Hydroprogne tschegrava tschegrava (Lepechin). Caspian Tern.—Rare.
Zenaidura macroura carolinensis (Linnaeus). Eastern Mourning Dove.—Rare summer resident.
Ectopistes migratorius (Linnaeus). Passenger Pigeon.—Extinct; formerly an abundant summer resident, breeding.
Coccyzus americanus americanus (Linnaeus). Yellow-billed Cuckoo.—Rare summer resident, June 21 to October 4. One specimen preserved.
Coccyzus erythrophthalmus (Wilson). Black-billed Cuckoo.—Uncommon summer resident, May 22 to August 23.
Bubo virginianus virginianus (Gmelin). Great Horned Owl.—Uncommon permanent resident. Breeds.
Nyctea nyctea (Linnaeus). Snowy Owl.—Uncommon winter visitant, November to April.
Strix varia varia Barton. Northern Barred Owl.—Common permanent resident.
Scotiaptex nebulosa nebulosa (Forster). Great Gray Owl.—Rare winter visitant.
Asio wilsonianus (Lesson). Long-eared Owl.—Rare.
Asio flammeus flammeus (Pontoppidan). Short-eared Owl.—Rare.

Cryptoglaux funerea richardsoni (Bonaparte). Richardson's Owl.—Rare. One specimen preserved.

Cryptoglaux acadica acadica (Gmelin). Saw-whet Owl.—Rare. One specimen preserved.

Antrostomus vociferus vociferus (Wilson). Eastern Whip-poor-will.—Uncommon summer resident, June 2 until August.

Chordeiles minor minor (Forster). Eastern Nighthawk.—Common summer resident, May 23 to September 15. Breeds. One specimen preserved.

Chaetura pelagica (Linnaeus). Chimney Swift.—Common summer resident, May 10 to September 15. Breeds.

Archilochus colubris (Linnaeus). Ruby-throated Hummingbird.—Uncommon summer resident, May 31 to September 8.

Megaceryle alcyon alcyon (Linnaeus). Eastern Belted Kingfisher.—Common summer resident, April 1 to October 21. Breeds.

Colaptes auratus luteus Bangs. Northern Flicker.—Common summer resident, April 22 to October 18. Breeds.

Ceophloeus pileatus abieticola Bangs. Northern Pileated Woodpecker.—Common permanent resident. Breeds.

Melanerpes erythrocephalus erythrocephalus (Linnaeus). Eastern Red-headed Woodpecker.—Rare.

Sphyrapicus varius varius (Linnaeus). Yellow-bellied Sapsucker.—Uncommon summer resident, April 20 to October 6.

Dryobates villosus villosus (Linnaeus). Eastern Hairy Woodpecker.—Common permanent resident. Breeds. One specimen preserved.

Dryobates pubescens medianus (Swainson). Northern Downy Woodpecker.—Common permanent resident. Two specimens collected.

Picoides arcticus (Swainson). Arctic Three-toed Woodpecker.—Uncommon permanent resident. Breeds.

Picoides tridactylus bacatus Bangs. American Three-toed Woodpecker.—Rare.

Tyrannus tyrannus (Linnaeus). Eastern Kingbird.—Common summer resident, May 17 to September 19. Breeds.

Tyrannus verticalis Say. Arkansas Kingbird.—Rare.

Myiarchus crinitus boreus Bangs. Northern Crested Flycatcher.—Rare summer resident. Breeds.

Sayornis phoebe (Latham). Eastern Phoebe.—Common summer resident, May 7 to October 1. Breeds.

Empidonax trailli trailli (Audubon). Alder Flycatcher.—Uncommon summer resident, May 23 to July 14, and probably later.

Empidonax minimus (W. M. and S. F. Baird). Least Flycatcher.—Common summer resident, May 19 to August 19. Breeds.

Myiochanes virens (Linnaeus). Eastern Wood Pewee.—Common summer resident, May 23 to September 21. Breeds.

Nuttallornis borealis cooperi (Nuttall). Eastern Olive-sided Flycatcher.—Uncommon summer resident, May 29 to August 8. Breeds.

Otocoris alpestris alpestris (Linnaeus). Northern Horned Lark.—Common transient, September 24 to October 16.

Iridoprocne bicolor (Vieillot). Tree Swallow.—Common summer resident, April 21 to September 18. Breeds.

Stelgidopteryx ruficollis serripennis (Audubon). Rough-winged Swallow.—Rare summer resident.

Hirundo rustica erythrogaster Boddaert. Barn Swallow.—Common summer resident, May 9 to September 2. Breeds.

Petrochelidon albifrons albifrons (Rafinesque). Northern Cliff Swallow.—Uncommon transient.

Progne subis subis (Linnaeus). Purple Martin.—Uncommon summer resident, May 24 to September 8.

Perisoreus canadensis canadensis (Linnaeus). Canada Jay.—Uncommon permanent resident. Breeds. One specimen preserved.

Cyanocitta cristata bromia Oberholser. Northern Blue Jay.—Common permanent resident, less frequent in winter. Breeds. One specimen preserved.

Corvus corax europhilus Oberholser. Southern Raven.—Common permanent resident.

Corvus corone brachyrhynchos Brehm. Eastern Crow.—Common summer resident, March 4 to October 19. Breeds.

Penthestes atricapillus atricapillus Linnaeus. Black-capped Chickadee.—Common permanent resident. Breeds. Two specimens preserved.

Penthestes hudsonicus hudsonicus Forster. Hudsonian Chickadee.—Rare permanent resident.

Sitta carolinensis carolinensis Latham. White-breasted Nuthatch.—Uncommon permanent resident. Two specimens preserved.

Sitta canadensis canadensis Linnaeus. Red-breasted Nuthatch.—Common permanent resident. Two specimens preserved.

Certhia familiaris americana Bonaparte. Brown Creeper.—Uncommon summer resident, March 16 to October 11. Breeds.

Troglodytes aëdon subsp. House Wren.—Uncommon summer resident, May 20 to July 14, and doubtless later. Breeds.

Nannus hiemalis hiemalis (Vieillot). Eastern Winter Wren.—Common summer resident, April 12 to October 14. Breeds.

Cistothorus stellaris (Naumann). Short-billed Marsh Wren.—Uncommon summer resident, June 16 to July 11, and doubtless later. Breeds.

Dumetella carolinensis (Linnaeus). Catbird.—Rare summer resident.

Toxostoma rufum (Linnaeus). Brown Thrasher.—Rare summer resident, May 21 to June 23, and probably later.

Turdus migratorius migratorius Linnaeus. Eastern Robin.—Common summer resident, April 18 to October 16. Breeds. One specimen preserved.

Hylocichla mustelina (Gmelin). Wood Thrush.—Uncommon summer resident, June 1 to July 12, and probably later.

Hylocichla guttata faxoni Bangs and Penard. Eastern Hermit Thrush.—Common summer resident, April 17 to October 17. Breeds.

Hylocichla ustulata swainsoni (Tschudi). Olive-backed Thrush.—Common summer resident, May 24 to September 25. Breeds.

Hylocichla minima aliciae (Baird). Gray-cheeked Thrush.—Rare transient, May 15 to 26 and September 7 to 23.

Hylocichla fuscescens subsp. Veery.—Uncommon summer resident, May 27 to September 21.

Sialia sialis sialis (Linnaeus). Eastern Bluebird.—Rare summer resident, May 8 to October 6.

Regulus regulus satrapa Lichtenstein. Eastern Golden-crowned Kinglet.—Uncommon summer resident, April 13 to October 22.

Regulus calendula calendula (Linnaeus). Eastern Ruby-crowned Kinglet.—Rare summer resident, May 25 to October 7.

Anthus spinoletta rubescens (Tunstall). American Pipit.—Rare transient, September 24 to November 1.

Bombycilla cedrorum Vieillot. Cedar Waxwing.—Common summer resident, May 30 to September 18.

Sturnus vulgaris vulgaris Linnaeus. Starling.—Uncommon summer resident.

Vireo solitarius solitarius (Wilson). Blue-headed Vireo.—Uncommon summer resident, May 19 to October 4. Breeds.

Vireo olivaceus (Linnaeus). Red-eyed Vireo.—Common summer resident, May 12 to October 2.

Mniotilta varia (Linnaeus). Black and White Warbler.—Uncommon summer resident, May 12 to September 5.

Vermivora peregrina (Wilson). Tennessee Warbler.—Rare fall transient.

Vermivora ruficapilla ruficapilla (Wilson). Nashville Warbler.—Common summer resident, May 21 to September 27.

Compsothlypis americana pusilla (Wilson). Northern Parula Warbler.—Common summer resident, May 24 to September 6. Breeds.

Dendroica aestiva aestiva (Gmelin). Eastern Yellow Warbler.—Uncommon summer resident, May 16 to August 23.

Dendroica magnolia (Wilson). Magnolia Warbler.—Uncommon summer resident, May 27 to August 28. Breeds.

Dendroica tigrina (Gmelin). Cape May Warbler.—Rare transient, May 20 to 29 and on September 20.

Dendroica caerulescens caerulescens (Gmelin). Black-throated Blue Warbler.—Uncommon summer resident, May 31 to September 23.

Dendroica coronata (Linnaeus). Myrtle Warbler.—Abundant summer resident, May 7 to October 3. Breeds.

Dendroica virens virens (Gmelin). Black-throated Green Warbler.—Abundant summer resident, May 10 to September 6. Breeds.

Dendroica fusca (Müller). Blackburnian Warbler.—Common summer resident, May 20 to September 6. Breeds.

Dendroica pensylvanica (Linnaeus). Chestnut-sided Warbler.—Uncommon summer resident, May 28 to July 24, and probably later.

Dendroica castanea (Wilson). Bay-breasted Warbler.—Rare transient, May 22 to 29.

Dendroica striata (Forster). Black-poll Warbler.—Rare transient, May 24 and 25.

Dendroica pinus pinus (Wilson). Northern Pine Warbler.—Common summer resident, May 8 to September 26.

Dendroica palmarum palmarum (Gmelin). Western Palm Warbler.—Common transient, May 9 to 23 and September 12 to October 4.

Seiurus aurocapillus (Linnaeus). Ovenbird.—Common summer resident, May 20 to September 10. Breeds.

Sciurus noveboracensis noveboracensis (Gmelin). Northern Water-thrush.—Uncommon summer resident, June 23 to September 19.

Oporornis philadelphia (Wilson). Mourning Warbler.—Uncommon summer resident, May 20 to August 6. Breeds.

Geothlypis trichas brachidactyla (Swainson). Northern Yellow-throat.—Uncommon summer resident, May 15 to September 21.

Wilsonia pusilla pusilla (Wilson). Wilson's Warbler.—Rare summer resident, May 28 to August 24.

Wilsonia canadensis (Linnaeus). Canada Warbler.—Uncommon summer resident, May 16 to July 6.

Setophaga ruticilla (Linnaeus). American Redstart.—Common summer resident, May 16 to September 19. Breeds.

Passer domesticus domesticus (Linnaeus). English Sparrow.—Uncommon permanent resident. Breeds.

Dolichonyx oryzivorus (Linnaeus). Bobolink.—Uncommon summer resident, June 13 to July 21; probably arrived since 1915-20.

Sturnella magna magna (Linnaeus). Eastern Meadowlark.—Rare summer resident, May 26 to September 13.

Sturnella neglecta Audubon. Western Meadowlark.—Rare summer resident.

Agelaius phoeniceus phoeniceus (Linnaeus). Eastern Redwing.—Common summer resident, April 20 to August 20. Breeds.

Agelaius phoeniceus arctolegus Oberholser. Giant Redwing.—Rare.

Euphagus carolinus (Müller). Rusty Blackbird.—Common transient, April 19 to 26 and September 22 to October 22.

Quiscalus quiscula aeneus Ridgway. Bronzed Grackle.—Common summer resident, April 23 to October 16. Breeds.

Molothrus ater ater (Boddaert). Eastern Cowbird.—Common summer resident, May 9 to September 21. Breeds.

Piranga erythromelas Vieillot. Scarlet Tanager.—Uncommon summer resident, May 20 to September 9.

Richmondena cardinalis cardinalis (Linnaeus). Eastern Cardinal.—Rare.

Hedymeles ludovicianus (Linnaeus). Rose-breasted Grosbeak.—Common summer resident, May 13 to July 19. Breeds.

Passerina cyanea (Linnaeus). Indigo Bunting.—Rare.

Hesperiphona vespertina vespertina (Cooper). Eastern Evening Grosbeak.—Uncommon summer resident, May 31 to October 23. Breeds.

Carpodacus purpureus purpureus (Gmelin). Eastern Purple Finch.—Uncommon summer resident, May 8 to November 10.

Pinicola enucleator leucura (Müller). Canadian Pine Grosbeak.—Uncommon winter visitant, September 3 to March 18.

Pinicola enucleator eschatosus Oberholser. Eastern Pine Grosbeak.—Rare winter visitant.

Acanthis linaria linaria (Linnaeus). Common Redpoll.—Common winter visitant, January 28 to April 10. Five specimens preserved.

Acanthis linaria rostrata (Coues). Greater Redpoll.—Rare winter visitant. One specimen preserved.

Spinus pinus pinus (Wilson). Northern Pine Siskin.—Uncommon permanent resident. Two specimens preserved.

Spinus tristis tristis (Linnaeus). Eastern Goldfinch.—Uncommon summer resident, May 5 to September 19.

Loxia curvirostra minor (Brehm). Red Crossbill.—Common summer resident, but observed in all months except December. Breeds. Seven specimens preserved. Other forms than *minor* probably also occur.

Loxia leucoptera leucoptera Gmelin. White-winged Crossbill.—Uncommon summer resident, and vagrant. Breeds. Seven specimens preserved.

Pipilo erythrophthalmus erythrophthalmus (Linnaeus). Red-eyed Towhee.—Uncommon summer resident, May 11 to June 24 and probably later.

Passerculus sandwichensis savanna (Wilson). Eastern Savannah Sparrow.—Uncommon summer resident, May 8 to October 12.

Ammodramus savannarum australis Maynard. Eastern Grasshopper Sparrow.—Rare summer resident.

Ammospiza caudacuta nelsoni (J. A. Allen). Nelson's Sparrow.—Rare.

Pooecetes gramineus gramineus (Gmelin). Eastern Vesper Sparrow.—Uncommon summer resident, May 8 to October 1.

Junco hyemalis hyemalis (Linnaeus). Slate-colored Junco.—Common summer resident, March 31 to November 11, and occasionally in winter. Breeds.

Spizella arborea arborea (Wilson). Eastern Tree Sparrow.—Uncommon transient, April 7 to 17 and September 19 to October 22.

Spizella passerina passerina (Bechstein). Eastern Chipping Sparrow.—Common summer resident, May 9 to October 12. Breeds.

Spizella pusilla pusilla (Wilson). Eastern Field Sparrow.—Uncommon, in September.

Zonotrichia querula (Nuttall). Harris's Sparrow.—Rare transient, September 24 to October 13.

Zonotrichia leucophrys leucophrys (Forster). White-crowned Sparrow.—Uncommon transient, May 14 to 21 and August 29 to October 7.

Zonotrichia gambeli (Nuttall). Gambel's Sparrow.—Rare.

Zonotrichia albicollis (Gmelin). White-throated Sparrow.—Common summer resident, May 8 to October 17.

Passerella iliaca iliaca (Merrem). Eastern Fox Sparrow.—Uncommon transient, April 7 and September 17 to October 22.

Melospiza lincolni lincolni (Audubon). Lincoln's Sparrow.—Rare transient, September 8 to 13.

Melospiza georgiana (Latham). Swamp Sparrow.—Common summer resident, April 27 to October 8.

Melospiza melodia subsp. Song Sparrow.—Common summer resident, April 17 to November 1. Breeds.

Calcarius lapponicus lapponicus (Linnaeus). Lapland Longspur.—Uncommon transient, September 21 to October 28.

Plectrophenax nivalis nivalis (Linnaeus). Eastern Snow Bunting.—Common transient, March 27 to 29 and October 9 to December 14.

MAMMALS

Condylura cristata (Linnaeus). Star-nosed Mole.—Workings are frequently seen in damp lowlands and along streams. One was collected near Gwinn, Marquette County, by John N. Lowe on June 21, 1926. Another was taken along Wilson Creek by J. J. Abbott on November 10, 1939, and a third in a weir on the Salmon Trout River by F. W. Taber on July 8, 1941. The last two specimens were preserved by the writer.

Sorex cinereus cinereus Kerr. Masked Shrew.—This was the most common shrew in the region except during 1942. It was found in nearly all types of habitat but seemed to prefer areas of considerable moisture, especially coniferous swamps. Forty-nine specimens were preserved.

Sorex palustris hydrobadistes Jackson. Water Shrew.—Known from three specimens, one collected by W. P. Harris, Jr., in a swamp at the west end of Pine Lake on August 27, 1930; one taken by me at the same locality on August 28, 1940; and the third found dead along the trail near the Test Pier, by George Campbell, on July 21, 1941.

Microsorex hoyi intervectus Jackson. Pygmy Shrew.—This rare shrew is known in the Huron Mountains from three specimens, two of which I preserved. These two were taken in swamps of leatherleaf and of white cedar, respectively; the third was recovered by L. L. Smith, Jr., from the stomach of a brook trout caught in the Salmon Trout River.

Blarina brevicauda kirtlandi Bole and Moulthrop. Short-tailed Shrew.—This shrew was very scarce in some years, and plentiful in others. In 1942 it was the most abundant small mammal in the region. It is usually found in relatively damp situations, but its distribution seems less influenced by moisture than is the case with the masked shrew. I preserved forty-six specimens.

Myotis lucifugus lucifugus (Le Conte). Little Brown Bat.—This is the common bat in the Huron Mountains during the summer, when it is seen flying over water and occasionally in buildings. It has been observed from June 6 until October 7; it probably migrates south in winter, although Douglas Mills reports that he and Fred L. Dunham once found dozens of these bats in a hollow hemlock along lower Mountain Streams, in the dead of winter. Two males were collected by C. D. Mattson on August 24, 1940 from beneath a stone along lower Fisher Creek. I preserved ten specimens.

Myotis keenii septentrionalis (Trouessart). Keen Bat.—Known from one specimen taken at the Club by W. P. Harris, Jr., on August 28, 1936.

Eptesicus fuscus fuscus (Peale and Beauvois). Large Brown Bat.—One was collected by W. P. Harris, Jr., on September 2, 1926. I preserved another taken in a cabin by Mrs. R. A. Hibbs on September 9, 1940.

Lasirius borealis borealis (Muller). Red Bat.—There are no Marquette County records at hand, although specimens have been taken in Chippewa

and Gogebic counties. On October 20, 1939, I saw one bat, appearing to be this species, flying in early evening along the trail from Mountain Lake to Trout Lake.

Ursus americanus americanus Pallas. Black Bear.— Bears are occasionally encountered along the trails, and tracks and sign are frequently seen. Not uncommonly, bears visit the guards' camps on Cedar Creek and the Salmon Trout River; in earlier years they visted the garbage dump (now abandoned) in the evenings, especially in the autumn. Several times they have killed pigs at the Club Farm or at nearby logging camps. One was shot at the Club Farm in 1938; two were shot in each of the 1939 and 1941 hunting seasons.

Procyon lotor lotor (Linnaeus). Raccoon.—This is a rare species this far north. Leopold (1939) reported one caught at the Jensen homestead about 1920. One frequented the Club kitchen about 1925. On November 13, 1939, I saw one near the mouth of Mountain Stream. The skin of a raccoon from this area is in the possession of Victor Elting.

Martes americana americana (Turton). Marten.—This species is now absent or extremely rare in the Huron Mountains. Wood and Dice (1924) reported it common in Schoolcraft County the winter of 1875-76. Ames (1906) "trapped last winter 6 marten" at Forsyth, Marquette County. Speedy (1906) said it was present on St. John's Lake, far up the Michigamme River. Bruce (1910) stated that one Marquette County trapper caught $100 worth in 1907, but that it was "pretty nearly exterminated" by 1910. It has been seen or trapped in the Huron Mountains by "Indian Jim" Dakota and by Gottlieb Rudat; the latter reports that it became scarce when the pine was cut, presumably because of the decrease in red squirrels. In January 1932 "few signs" were seen by Kenneth Ganroth, a predatory animal hunter. As late as November 1937 one was seen by H. E. Perkins near The Norways on Mountain Lake; and in the spring of 1939 J. J. Abbott reported one near the Murphy Cabin on the Salmon Trout River.

Martes pennanti (Erxleben). Fisher.—Probably now extirpated in the Huron Mountains. Wood and Dice (1924) reported it common in Alger and Schoolcraft counties the winter of 1875-76. Oliver Morris reports that it was present, but not common, in the Huron Mountains about 1900. Ames (1906) stated that four were caught in Marquette County the winter of 1905. It has been trapped by "Indian Jim" Dakota, and one was taken by Gottlieb Rudat about 1927 near his homestead. The skin of the latter was given to H. E. Perkins, and is now preserved at the Museum of Zoology (No. 87312). At about this same time one was trapped by Jake Harig at Canyon Lake, but was not preserved. Two were killed in 1930-31 by John Bennett, a trapper stationed at the Club; their skulls and one skin have been preserved by W. P. Harris, Jr. In January, 1932, Kenneth Ganroth, a predatory animal hunter, noted "few signs." Leopold (1939) reported that sign was seen (by Fred L. Dunham?) along the Salmon Trout River about 1936.

Mustela erminea cicognanii Bonaparte. Short-tailed Weasel.—This is the common weasel of the Huron Mountains. Of six specimens preserved, those

taken from December to February are in the white winter pelage.

Mustela frenata noveboracensis (Emmons). Long-tailed Weasel.—This large weasel is known in the Huron Mountains from three specimens collected by W. P. Harris, Jr., H. E. Perkins, and myself. The pelage is just beginning to turn white in one taken on November 4, 1939. A fourth specimen, not preserved, was killed while raiding a chicken yard by Walter Krieg on October 20, 1940.

Mustela vison vison Schreber. Mink.—This fearless animal is rather commonly seen along the shores of lakes and streams; its tracks are frequent on sandy beaches. On May 28, 1940, I observed what appeared to be mating behavior near the Pine Lake boathouses. One mink, of a lighter color and with a smaller white patch on the chin, chased a second into a hollow log on the shore. After a short commotion the first emerged with a spot of blood on its throat. Presently the other appeared. For several minutes they played on the log and along the shore, and then went off in opposite directions. A family was raised in this vicinity the same summer. Among 14 scats collected, remains of red squirrel, flying squirrel, deer mouse, an unidentified bird, black bass, yellow perch, and insects appeared in one each; meadow vole, muskrat, a frog, and rock bass were each represented in two; and crayfish remains were found in seven. I have preserved one mink skin from the region.

Gulo luscus Linnaeus. Wolverine.—The wolverine has now apparently been extirpated in Michigan. Cory (1912:353) wrote: "Old trappers living near Champion claim that wolverines were occasionally killed there thirty or thirty-five years ago." Wood (1914) listed Michigan trapping records from eight counties, but not Marquette. Wood and Dice (1924) cited four trapping records in Chippewa, Kent, Oscoda, and Schoolcraft counties. Schorger (1939) brought to light a note on the capture of a wolverine near Marquette on February 15, 1860. Shoemaker (1939:32) stated that the wolverine disappeared in Michigan about 1880, but cited no evidence to substantiate this. Gottlieb Rudat, who has resided in the Huron Mountains since 1903, reports that it was never common, but that he did see one along the Dead River "long ago." "Indian Jim" Dakota claims to have taken two on the Peshekee River, north of Lake Michigamme, about 1928-30.

Lutra canadensis canadensis (Schreber). River Otter.—This is a regular, but not abundant, inhabitant of the Huron Mountains. Otters are known to travel great distances overland, seldom remaining for long in one locality. In 1941, otters were seen in the region by various individuals on at least eight occasions; three times I saw pairs of otters. Two were trapped in Lake Independence the spring of 1940. Among 13 scats collected, remains of meadow vole, muskrat, frog, salamander, yellow perch, muddler, and burbot were found in one each; sucker and minnow in two; rock bass in three; unidentified fish in four; and trout, insects, and crayfish in five. An otter skin from the Huron Mountains has been preserved by Victor Elting, and a skull by W. P. Harris, Jr.

Mephitis mephitis hudsonica Richardson. Striped Skunk.—A tolerably common animal in this region. From August to October, 1932, nine were taken

by Kenneth Ganroth, and in August, 1933, two by Marion Collins. The skunk goes into semi-hibernation during the colder months; I saw no signs of its activity from October 3, 1939 until March 26, 1940. W. P. Harris, Jr., and Victor Elting have preserved specimens. On September 14, 1940, one was trapped by C. D. Mattson near the Club garages.

Taxidea taxus taxus (Schreber). Badger.—An uncommon animal in the Huron Mountains. H. E. Perkins reported seeing one near Ives Lake in the past. Longyear Palmer reported one near Howe Lake on July 5, 1941. The only other records are from predatory animal hunters, who failed to preserve specimens. Two were reported taken in 1927 near the Yellow Dog River; one near the Salmon Trout River in 1933 by Marion Collins; and one (near Ishpeming?) in 1933 by Ben Filmonski.

Vulpes fulva (Desmarest). Red Fox.—Common and widespread in the region. Tracks are frequently seen, especially along streams or lake shores, or in light forest. Twenty-three were killed in 1932 and 1933 by three professional hunters. Several dens at the Chicken Farm were poisoned in 1941 by a Conservation Officer. L. L. Smith, Jr., saw three foxes at the Pine River bridge on October 16, 1939; I have seen them on six occasions. Tracks indicated mating in the center of First Pine Lake on February 13, 1940. In 1941 there were two or more dens among jack pines near the Fournier homestead; not far distant I saw an adult and three young, along Pine River, on June 19, 1941. Analysis of 21 scats showed woodchuck, meadow vole, deer, ruffed grouse, and young snapping turtle remains in one each; red squirrel, deer mouse, and porcupine in two; unidentified seeds in five; insects in six; and snowshoe hare in fourteen. I preserved two fox skulls.

Canis latrans latrans Say. Coyote.—This species has invaded the Upper Peninsula of Michigan from the west since the turn of the century, and has become so numerous as to have a bounty levied upon it. Wood and Dice (1924) reported one taken near Munising, Alger County, in March, 1912. C. V. Woodin reported a few in Marquette County in 1913. In the Huron Mountains coyotes have been trapped by predatory animal hunters as follows: 1932, six by Kenneth Ganroth, thirty-three by Ben Filmonski (near Ishpeming); 1933, fifteen by Marion Collins. In December, 1935, seven were taken on Club lands by Fred L. Dunham; he reported two others seen in January and February, 1938. Two coyotes were shot during the 1941 hunting season. Coyotes appear to be more plentiful in the Huron Mountains during the winter. They do but slight damage to deer, subsisting largely on rabbits and smaller animals; deer eaten are probably consumed as carrion for the most part. I collected 34 coyote scats; analysis showed least chipmunk, red squirrel, and meadow jumping mouse remains in one each; eastern chipmunk, meadow vole, insects, and vegetation in two; woodchuck in three; muskrat in four; deer in six; porcupine in twelve; and snowshoe hare remains in nineteen scats.

Canis lupus lycaon Schreber. Timber Wolf.—This species is native to the Upper Peninsula, but is now close to extermination. One was killed in the Huron Mountains by Kenneth Ganroth in September, 1932; Ben Filmonski took six in 1932 near Ishpeming. Packs of from two to seven were reported

in the Huron Mountains by Fred L. Dunham on six occasions from December 28, 1937 until April 12, 1938. He reported nine deer killed by wolves the spring of 1937, and seven the spring of 1938. Among five wolf scats which I collected, deer mouse and meadow jumping mouse remains were present in one each; red squirrel, deer, and vegetation were each present in two scats; and three scats contained remains of snowshoe hare. Leopold (1939) reported a breeding den found at Mountain Lake about twenty-five years ago. Today wolves are extremely scarce in the region, although a few occasionally appear for brief periods.

Canis familiaris Linnaeus. Domestic Dog.—Occasionally domestic dogs go wild and thrive in the feral state, doing some damage to game and to wildlife generally. One such dog was killed near Rush Lake in August, 1933, by Marion Collins.

Felis concolor couguar Kerr. Cougar.—This species, also known as the panther or mountain lion, has long been regarded as extirpated in the state. Shoemaker (1939) reported that it disappeared in Michigan about 1900. However, at least three deer are known to have been killed and cached, in typical cougar fashion, at the Club in the autumn of 1932. Tappan Gregory has a photograph of one of these caches, taken near Pine Lake. Several more recent reports in the Huron Mountains are of interest. In 1937 a large cat, identified as this species by its size and long tail, was seen by several persons as late as August. H. E. Perkins saw it, once at close range, on three occasions near the Yellow Dog Swamp; it was reported along the Salmon Trout River by Mrs. Raymond E. Durham, Richard Turner, and Walter Krieg; workmen at the M-35 Cabin reported it; it was seen by Onnie Peura at Pine Lake; Prof. G. E. Nichols heard what he was convinced was a cougar at Mountain Lake. Harry Boulden of Big Bay claimed to have shot it, but it disappeared into the Yellow Dog Swamp; at any event, it was not subsequently reported. This cat was thought to have killed and cached at least one deer, near the Skeet Field. On July 14, 1940, Dr. Charles P. Drury and party reported seeing a cougar in the cutover land east of Conway Lake. On July 7, 1941, Howard Paul and party reported another near Big Bay. These last two reports, at least, may well have been cases of mistaken identity.

Felis domestica Linnaeus. House Cat.—Domestic cats frequently escape to the woods and do untold damage to wildlife. Four feral cats were trapped by Fred L. Dunham in December, 1935; seventeen others were trapped near the Club by William Marlowe during the winter of 1938-39. On was seen by S. M. Pell near the Salmon Trout River on June 29, 1941; on August 2, 1941 he saw one kill a rabbit near the Club Gate. Nearby one was shot by W. P. Harris, Jr., on October 6, 1941.

Lynx canadensis canadensis Kerr. Lynx.—This species doubtless once occurred in the Huron Mountains, but no recent records of its presence are available. Wood (1914) listed trapping records from Marquette County. Shoemaker (1939) stated, but gave no evidence, that it disappeared from Michigan about 1885. Harold du Charme states that he photographed both this species and the bobcat in the Huron Mountains many years ago.

Lynx rufus rufus (Schreber). Bobcat.—This native cat, also known as the wildcat or bay lynx, is present but not abundant in the region. One was trapped by Marion Collins in May, 1933; three were taken by Ben Filmonski, near Ishpeming, in 1932. Fred L. Dunham reported cats in groups of from two to five crossing the Club lands on five occasions from January 16 to March 1, 1938. One dead deer found by him on March 10, 1937, was attributed to the bobcat. This cat, however, feeds largely on rodents and smaller animals, and is not inimical to the deer herd. Mrs. Carroll Paul has the skin of a very large bobcat killed near the Salmon Trout River the autumn of 1936.

Marmota monax rufescens Howell. Woodchuck.—Fairly common and well distributed in this region, occupying woods (in particular jack pine and cutover hardwoods) as well as clearings. Twenty-six were killed in 1932-33 by two trappers. The woodchuck hibernates most of the winter; my earliest spring record was on March 26, 1940, and my latest fall record on October 11, 1940. A small woodchuck, frightened by a passing automobile, climbed a small jack pine to a height of fifteen feet until the danger was past. A family was raised near the Oscar Webster homestead in 1941; the two adults and five young were first seen in the open by Joseph Nuebarr on June 13. A young woodchuck was found wandering along the Salmon Trout River on May 27, 1942 by S. M. Pell. One specimen was collected by W. P. Harris, Jr., on September 20, 1928; I have preserved three others.

Eutamias minimus jacksoni Howell. Least Chipmunk.—This is by far the more common of the two species of chipmunks native to the Huron Mountains. It occurs at all elevations and in nearly all types of cover. It hibernated from approximately October 20, 1939 until April 18, 1940. I preserved twenty-three specimens.

Tamias striatus griseus Mearns. Eastern Chipmunk.—This chipmunk, also locally called the "gopher," is far less common in the Huron Mountains than is the least chipmunk. It is generally distributed, and is found at all elevations, but it seems to favor a dry habitat in deep shade. It appeared to hibernate from October 16, 1939 until March 30, 1940. I have preserved nine specimens.

Tamiasciurus hudsonicus loquax Bangs. Red Squirrel.—This is the most conspicuous mammal of the region; it occurs widely throughout the property, especially among conifers. It remains active all winter, feeding on stores of nuts, pine cones, and seeds gathered in the autumn. In 1941, it was unusually abundant. Three young made their first excursion out of the nest, near the Club, on June 20, 1941. I have preserved seven specimens; those taken in winter are of a brighter red color and lack the black lateral stripe of summer specimens.

Sciurus carolinensis hypophaeus Merriam. Gray Squirrel.—The gray squirrel is uncommon in this region, being near the northern limits of its range. Leopold (1939) reports sight records at Mountain Lake, Trout Lake, and Mountain Stream in 1937, and at the Salmon Trout bridge and at Howe Lake in 1938. It has been seen by B. H. Christy, Mrs. R. A. Hibbs, H. E. Perkins, John S. Perkins, and E. Rasmussen; on six occasions I have noted it, usually in the tree-tops of heavy hardwood or conifer forests. H. E. Perkins

and I have several times noted the black phase, always near the north shore of Second Pine Lake; D. M. Nason has also reported the black phase near the Five Forks. W. P. Harris, Jr., collected one specimen at Trout Lake on October 12, 1934; I preserved another taken near the Pine Lake boathouses on September 26, 1941.

Glaucomys sabrinus macrotis (Mearns). Northern Flying Squirrel.—This species is probably more common in the region than generally supposed. I observed three on October 15, 1939, in a deserted woodpecker hole in a dead Norway pine near Trout Lake. I preserved three specimens taken among jack pines and in an area of cutover hardwoods.

Castor canadensis michiganensis Bailey. Beaver.—The beaver is a common and widely distributed animal in the Huron Mountains. In swamps and lakes it inhabits the conventional lodge, but in the larger streams it constructs bank houses. Where its favorite food supply, the aspen, is exhausted, it often subsists on other vegetation. Cuttings have been noted on sugar, red, and striped maple, white and yellow birch, elm, mountain ash, pin cherry, tag alder, willow, and on white cedar, hemlock, and Norway pine. Possibly the conifers are used only for dams and lodges.

Beavers have probably inhabited this region for a long period. Morgan (1868:viii), whose classical work was done at Teal Lake and elsewhere near the present site of Ishpeming, said of the colonies which he examined: "It was evident that they had existed and been maintained for centuries." On a map of the Longyear Estate, made in 1895, Beaver Lake (east of lower Mountain Lake) was shown as an "old deserted beaver pond." Other very old beaver colonies occur along Mink Run, Elm Creek, the inlet of Anne Lake, at Lily Lake, and at Florence Pond. D. L. Hebard stated that beavers were absent in the Huron Mountains about 1885, and were scarce about 1910. Carter H. Harrison recalls that they were present in Pine River in 1901. In the autumn of 1940, I located at least twenty-four active colonies and over seventy deserted sites in the region. Nearly all lakes, streams, and open marshes in the area appear to have supported beaver at one time.

Their population at present is relatively stable. Few predators exact a heavy toll on them. Trapping has been slight for many years except in 1936, when twenty-four adults and four juveniles were poached from the Salmon Trout River. There was some illegal trapping on the Cliff River and at Conway Lake in April, 1940. I preserved three skulls.

Peromyscus maniculatus gracilis (Le Conte). Woodland Deer Mouse.—This is the most abundant mammal in the region during most periods. It occurs commonly in all types of forest. Together with the meadow vole and snowshoe hare, it comprises an important staple food of larger predators. Thirty-four specimens were preserved.

Synaptomys cooperi cooperi Baird. Bog-lemming.—This species is known in the Huron Mountains from one specimen (Museum of Zoology No. 59001) collected near Mountain Lake on July 3, 1927 by C. L. Hubbs.

Clethrionomys gapperi gapperi (Vigors). Red-backed Vole.—This species

is widespread and abundant in most types of forest, especially conifers, as well as in swamps and bogs. Fifty-eight specimens were preserved.

Microtus pennsylvanicus pennsylvanicus (Ord). Meadow Vole.—This vole is locally common in meadows or swamps, as at Lower Dam Pond or the west end of Pine Lake; seven were taken in a white cedar swamp. Nineteen specimens were preserved.

Ondatra zibethica zibethica (Linnaeus) Muskrat.—This species is common in the lakes and streams of the region. It occasionally builds lodges, as at the Cranberry Marsh, but more often inhabits bank houses. It is chiefly a vegetarian, but also feeds on mussels (*Anodonta marginata* Say), piles of whose shells are often found along shores or in boathouses. The muskrat can open this bivalve by biting through the hinge joining the two shells. Many empty shells, however, are entirely undamaged. Whole mussels, sometimes still alive, found along the shores lead to the conclusion that the muskrat deposits the mussels in the sun where they dry and open naturally, to be consumed later. One specimen was preserved.

Rattus norvegicus Berkenhout. House Rat.—Rats, probably of this species, were reported by H. E. Perkins as present at the Club until about 1906, when boats stopped landing there. None occur in the Huron Mountains today.

Mus musculus musculus Linnaeus. House Mouse.—This introduced species is occasionally found about the Club buildings and in cabins. Three specimens were preserved.

Zapus hudsonius hudsonius (Zimmermann). Meadow Jumping Mouse.—This mouse is probably rather common in grassy meadows and swampy lands, and was taken also among white birch and aspen and among hardwood saplings. Six specimens were preserved.

Napaeozapus insignis frutectanus Jackson. Woodland Jumping Mouse.—I captured two individuals, one of which was preserved; both were in a cutover area grown up to a tangle of hardwood saplings. The one preserved had a thick layer of subcutaneous fat on August 24, 1941.

Erethizon dorsatum dorsatum (Linnaeus). Porcupine.—This is a common animal in the Huron Mountains, despite the fact that hundreds of them have been needlessly killed by "predatory" animal hunters. In the summer of 1939, thirty-six were killed along Cedar Creek alone. The porcupine's favorite foods are the leaves, buds, and bark of hemlocks and aspen; it also eats white cedar, pin cherry, sugar and red maple, elm, basswood, red oak, and yellow birch. These feeding habits, however, do no appreciable injury to the forest as a whole. What appeared to be a prelude to mating was observed on the summit of Mount Homer on September 25, 1940; again, on September 16, 1941, two porcupines were together high in a basswood near the mouth of Mountain Stream, both whining and crying in a tone not unlike a baby's that could be heard distinctly several hundred feet away. Porcupines were unusually abundant in the Huron Mountains during the summer of 1942; I noted twenty in the course of thirty-one days afield. Five specimens were preserved.

Lepus americanus phaeonotus Allen. Snowshoe Hare.—The hare or snowshoe rabbit is common in such types of cover as jack pines, cutover hardwoods, and spruce or cedar swamps. It is a classic example of a cyclic species, which may be overwhelmingly abundant one year and practically nil a few years later. The last great peak in the cycle, in the Huron Mountains, appears to have been about 1925-26, when hares were extremely abundant and so lethargic that they could be kicked down in the woods. A disease seemed to reduce their population to normal limits, and at such times the natives would not eat them. I noted one killed by a fox, another by a feral house cat. There is much variation in the time of assuming the white winter pelage, but in general hares are white from late November until mid-April in this region. Partial change in color has been observed as early as October 12 and some white has persisted in the pelage until April 23. I collected five specimens.

Sylvilagus floridanus mearnsii (Allen). Cottontail.—Years ago this rabbit was restricted to the Lower Peninsula in Michigan and to southern Wisconsin. With the clearing of the land it has moved north and is now common in the city of Marquette, where Shiras (1936:344) stated it apparently arrived about 1920. Cottontails are hunted near Sugar Loaf Mountain, about ten miles northwest of Marquette, and have been seen near Big Bay and the Five Forks by Clarence Watt and myself. Unlike the hare, the cottontail does not change to white in winter.

Odocoileus virginianus borealis Miller. White-tailed Deer.—Hubbard (1887:356) reported the deer as "not known in our upper peninsula, on Lake Superior, as late as 1840." By 1890 they were plentiful in the Huron Mountains, and today they occur throughout the region. During the winter they tend to concentrate in the lowlands skirting the shore of Lake Superior, where the snow is less deep. They were estimated to reach a density of 21.6 per square mile in 1941. Browse species, particularly white cedar, hemlock, balsam fir, maples, and basswood, show heavy usage throughout their winter range. Further details on the Huron Mountain deer are presented elsewhere (Manville, 1947).

Alces americana americana (Clinton). Moose.—This species once occurred generally over the Upper Peninsula, but later became very rare or absent. Hubbard (1887:358) quoted an item from the *Portage-Lake Gazette* of April, 1869: "In the year 1847 there was a famous herd of wild moose living in the woods around the head of L'Anse Bay [Baraga County], but finally the herd were entrapped and all killed except one old leader stag, who broke away." Moose continued to exist in protected areas, such as Isle Royale. In 1934 seventy-one moose were released from Isle Royale to points on the Upper Peninsula mainland. Victor Johnson reported one seen along the road at Antlers about 1936, which may have been one of this herd. Carter H. Harrison and Oliver Morris each report that the moose was formerly unknown in the Huron Mountains. The nearest authentic record is that of a skeleton found in 1892 by N. M. Kauffman at the edge of Silver Lake, Alger County, about three miles southeast of Camp Peter White. In June, 1916, the antlers and basal portion of the skull of this specimen were found by Norman A. Wood

nailed to a tree near Kauffman's camp; they are preserved in the Museum of Zoology collection (No. 48727).

Rangifer caribou caribou (Gmelin). Caribou.—Egbert (1935) cites Hubbard as reporting the caribou present, but scarce, in the vicinity of Presque Isle in 1840. There is one verbal report of this species in Marquette County: George Shiras III relates that his old Indian guide, Jack La Pete, killed six caribou near Sand River, a few miles west of Camp Peter White, in 1865. The lack of other reports indicates that the caribou was never abundant here within the memory of white man.

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A Study of the Weaver Ant, Oecophylla smaragdina (Fab.)[1]

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Recent attention to certain ants of the Asiatic fauna has directed particular interest toward the genus *Oecophylla;*[2] specifically, to *Oecophylla smaragdina* (Fabricius). In reviewing available papers on the species, and in our investigations of collected material, certain features have seemed noteworthy. Also, we were made aware of the scarcity and remoteness of literature concerned with this most interesting genus. For these reasons, in presenting recent observations, a general report on the genus is included, although particular reference is devoted to *Oecophylla smaragdina.*

Taxonomy.—The following description of the genus is taken from Wheeler's report on the *Ants of the Belgian Congo* (1922).

"Worker medium-sized, slender, slightly polymorphic. Head rather large, broader behind than in front, with rounded sides and posterior corners and semicircularly excised occipital border, very convex above. Eyes large, convex, broadly elliptical, situated in front of the middle of the head. Ocelli absent. Palpi very short, maxillary pair 5-jointed, labial pair 4-jointed. Mandibles long and large, triangular, with nearly straight lateral borders, a very long curved apical tooth and numerous short denticles along the straight apical border. Clypeus very large and convex, but not distinctly carinate, its anterior border entire or very feebly sinuate in the middle, depressed and projecting over the bases of the mandibles. Frontal area rather large, subtriangular; frontal carinae moderately long, subparallel. Antennae very long, 12-jointed, the scapes inserted some distance from the posterior corners of the clypeus, rather abruptly incrassated at their tips; the first funicular joint very long and slender, longer than the second and third together, joints 2 to 5 much shorter, subequal, slender, the remaining joints except the last, shorter and distinctly thicker. Thorax long and narrow; pronotum longer than broad, evenly convex above, narrowed and colliform anteriorly; mesonotum anteriorly long and constricted, subcylindrical, suddenly broadened behind where it joins the small, short, unarmed epinotum, which is rounded and convex above and without distinct base and declivity. Petiole long and slender, much longer than broad, subcylindrical, with a very low rounded node near its posterior end, its ventral surface near the middle more or less convex, its posterior border on each side with a small rounded, projecting lamella, appearing like an acute tooth when the segment is viewed from above. Gaster short, broadly elliptical, its first segment suddenly contracted to the petiole, the tip rather pointed. Legs very long and slender; claws, pulvilli, and last tarsal joint enlarged. Gizzard with long slender sepals, which are not reflected at their anterior ends."

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1 Contribution no. 16, Dept. of Zoology & Entomology, Univ. of Tenn.

2 Described by F. Smith, Journ. Proc. Linn. Soc. Lond., Zool., Vol. 5, p. 102, 1861.

Taxonomically, the genus consists of two distinct species with their subspecies and varieties. One of these is *Oecophylla smaragdina* (Fab.) with two subspecies, *subnitida* Emery and *virescens* (Fab.) and with its three varieties, *selebensis* Emery, *gracilior* Forel and *gracillima* Emery. The other species is *Oecophylla longinoda* (Latreille) with four varieties: *textor* (Santschi), *rubriceps* (Forel), *annectans* Whlr. and *fusca* (Emery). These members of the genus are easily separated by Wheeler's key (1922) as follows:

1. Petiole very slender, its stigmata seen from above very prominent, its ventral surface nearly straight or very feebly convex in profile (*smaragdina*) 2
   Petiole stouter and higher, its stigmata seen from above not prominent, its ventral surface strongly convex in profile (*longinoda*) 7
2. Body ferruginous or testaceous 3
   Gaster and sometimes the head pea-green, head more rounded and less truncated behind; size smaller, petiole somewhat shorter (Queensland, New Guinea, the Islands Aru and Key) .....subspecies *virescens* (Fab.)
3. Integument opaque or subopaque 4
   Integument more or less distinctly shining 5
4. Color ferruginous (India, Ceylon, Cochin China, Indonesia) ....*smaragdina* (typical)
   Smaller and more testaceous, mesonotum and petiole a little narrower (Java) .....
   .....var. *gracilior* Forel
5. Large forms, integument slightly shining (Papua, Philippines, Melanesia) .....
   .....subspecies *subnitida* Emery
   Smaller forms, integument more shining 6
6. Body very shining and slender, color testaceous, head rather elongate .....
   .....var. *gracillima* Emery
   Less shining and less slender, head shorter (Celebes) .....var. *selebensis* Emery
7. Ferruginous or testaceous throughout 8
   Brown or black 9
8. Color ferruginous (West Africa) .....*longinoda* (typical)
   Color paler, more testaceous, petiole shorter, head slightly broader, apical tooth of mandibles shorter (Zanzibar) .....var. *textor* (Santschi)
9. At least the thorax and mandibles black 10
   Body rather uniformly brown (Belgian Congo) .....
   .....var. *annectens* Wheeler
10. Head dull red, gaster often brownish (Belgian Congo) .....var. *rubriceps* (Forel)
    Head and gaster black or dark brown (Belgian Congo, Nigeria, Liberia, Cameroon, Spanish Guinea) .....var. *fusca* (Emery)

Distribution.—A tabulation of records shows that the genus is confined to the Old World Tropics, ranging over the Indo-Malayan, Papuan and Ethiopian regions but does not occur in Madagascar. *O. smaragdina*, with its subspecies and varieties, ocurs in the Ethiopian region. At one point in his discussion Wheeler remarks, "Several authors have cited the true *smaragdina* from east Africa. Unfortunately I have little material from that region and what I have is certainly *longinoda*, presumably belonging to *textor*, though this variety seems to me to be poorly characterized and possibly not distinct from the typical form of the species. I am unable to say, therefore, whether *Oecophylla smaragdina* actually occurs on the African Continent."

Dr. M. R. Smith[3] has stated that he believes the form most commonly recorded from Australia to be *Oecophylla smaragdina* in the broad sense and has kindly furnished us with a specimen of the subspecies *virescens* in the collection of Pergande and bearing the locality label "Central Australia."

Dodd (1902) has collected the species in Australia and has reported on *Notes on the Queensland Green Tree Ant,* doubtless in reference to *Oecophylla smaragdina* subsp. *virescens.*

Döflein (1905) gives interesting acocunts of the species from Ceylon and mentions records from western India at Bombay.

Mr. Fredric Smith (1864), past assistant in zoology at the British Museum, listed *Oecophylla smaragdina* from the islands of the Eastern Archipelago; specifically, the islands of Mysol, Timor, Waigion; Gilolo; Bachian; Dory; Aru; Borneo; the Philippines; and from Java, these records constituting a part of the report on the Hymenoptera collected by Mr. A. R. Wallace in the Eastern Archipelago. In a following report (1864) Smith adds Malacca, China, Celebes and Sumatra. He further states: "I have considerable doubts of its (*O. smaragdina*) being really specifically distinct from the African species *Oecophylla virescens,* which insect also occurs in Australia."

Other writers have referred to the "red tree ant" of the old world tropics and have listed the genus from Australia, India and Africa.

Although Forel (1894) states, ". . . *Oecophylla smaragdina,* one of the most common ants of tropical Africa . . .," it can now be shown that this species is not known from the Ethiopian region, *longinoda* being restricted to the continent of Africa and, in all probability, the species to which Forel has reference.

Other records of distribution of the genus include Weber's (1946) specimens of *O. longinoda* from the Belgian Congo, Mafia Island, Tanganyika, the Sudan, West Africa and Akkra. In addition, Keuchenius (1914) reports *O. smaragdina* from Java.

Colonel Bingham (1903) records the species from the whole of India, Burma and Ceylon except in the desert and treeless tracts, also listing the ant from Australia and New Guinea.

It is interesting to note that fossil forms representing four species of *Oecophylla* are to be found in European Tertiary deposits. *O. brischkei* is known from Baltic amber and *O. sicula* from the Sicilian amber deposits, both of the early Oligocene age and both species closely related to *smaragdina.* These constitute the only known fossil records of the genus, indicating that present day distributions are relicts, probably due to former land connections.

Biology.—The genus *Oecophylla,* together with two other genera (*Camponotus* and *Polyrhachis*) of the same subfamily are unique among ants in that some of the species construct nests largely made up of silk produced by the larvae, in which case the larvae themselves are used as tools. In the case of both *Oecophylla longinoda* and *smaragdina* the larvae are utilized as "shuttles" held by the mandibles of the minima worker caste in fastening leaves together into a nest. Here then, is a case in which the larvae are actually

3 By personal correspondence.

known to produce silk, but the pupae of these larvae are always nude. In each instance it has been observed that only immature larvae are utilized in producing the silk used in nest construction and that the well developed larvae are not utilized in producing this material.

The nests of *O. smaragdina* are generally confined to the scrubs and not commonly found in the forest proper. The species is polydomous and nests of varying sizes form "patches" in trees of which the foliage may be sparse (See Fig. 2). Frequently the old nests may be abandoned when the leaves become withered. No queens or winged forms were present in any of the nests examined nor was a winged individual found among the hundreds of specimens collected in India, although larvae were present in relative abundance. Dodd (1902) has written: "It is astonishing what myriads of inmates these nests contain; many of the chambers appear to be almost filled with the ants and their pupae and larvae. A new nest may be torn open, and though many larvae are present, no queen can be discovered; perhaps the queen may live in a central nest. . . ." Later Dodd (1902) asks the question, "Do queens live any length of time, or do they die at the approach of winter, leaving enough eggs to supply larvae to the several colonies for some weeks or even months?" In another paper (1902), this same author states: "During the wet season, queens

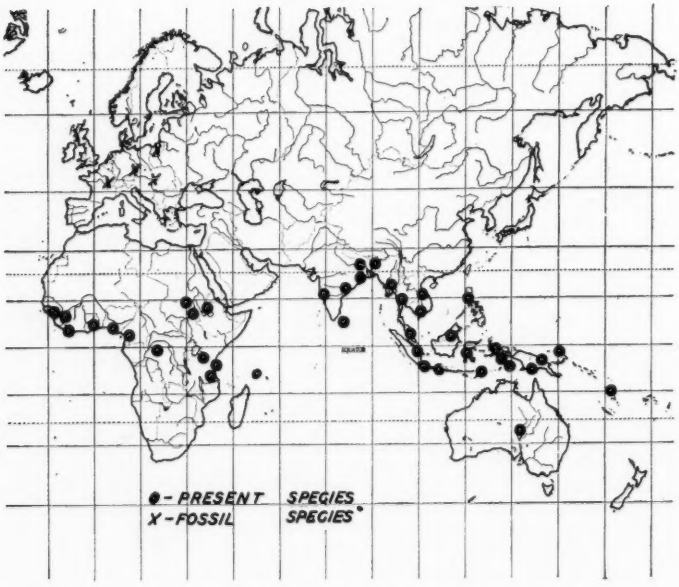

Fig. 1.— A map of the east showing range of the genus *Oecophylla* and its fossil species.

may be found singly throughout the scrubs in little retreats formed by few leaves."

The nests examined by the senior author represented myriads of all sizes and positions, including the succursals and shelters some distance from the nest, yet the grass-green females and the black males were not found.

Fig. 2.—Nests of *Oecophylla smaragdina* in trees, Upper Assam, India. Photo by A. C. Cole, Jr.

Fig. 3.—Typical nest of *Oecophylla smaragdina*. Photo by A. C. Cole, Jr.

It is interesting to note that food is not stored within the nest of the species but that the ants do tend aphids, feeding upon the exudates of the scales, and also commonly attend Lycaenid larvae. Frequently the larvae and aphids may be found within shelters constructed in the same fashion as the primary nests and approximate to these nests. Indeed, Keuchenius (1914) holds the view that *Oecophylla smaragdina* is very noxious to coffee plantations through its habit of keeping and protecting in its nests the green coffee scale, *Lecanium viride,* a most serious pest of the coffee tree.

The workers do not possess a sting but are nevertheless very effective in defending themselves and the nests from invasion by the instinctive pattern of biting rather severely and then ejecting a "spray" of formic acid from the tip of the abdomen, the gaster having been turned forward beneath the head and directed to the area of the bite.

Dimorphism.—The observations published by Weber (1946) concerning dimorphism and possible caste division among workers of the African species *longinoda,* were concurrent with similar observations of the impressive size variation in workers of the Asiatic species collected by the senior author in the interior province of Assam in northeastern India during 1943 and 1944. Moreover, it had been noted that Wheeler (1910) referred to the workers of the genus as "monomorphic," yet postulated a possible division of labor: "A remarkable example of division of labor, without corresponding structural differentiation, is seen also in the *Oecophylla,* an ant which inhabits nests of leaves sewn together with fine silk. According to the observations of Dodd (1902) and Döflein (1905), when the nests are torn apart the monomorphic workers separate into two companies, one of which stations itself on the outside of the nest, draws the separated leaves together and holds them in place with the claws and mandibles, while the other moves the spinning larvae back and forth within the nest till the rent is repaired with silken tissue." Still more interesting is the direct speculation of Döflein (1905), which the authors have translated as follows: "We saw that an interesting division of labor between the different individuals of the *Oecophylla* enables them to carry on a surprisingly artful building activity. Is it not possible that all individuals take over in the different roles, or do we find a differentiation of the instincts in special individuals? Do we find that they are actually morphologically differentiated? That is, are there worker castes which we can distinguish by their morphology, each of which is associated with a special task? I was made aware of this possibility by questions during a lecture because the material which was put on exhibition during the lecture showed small workers as bearers of the larvae and also, side by side, the large workers. Actually it can be shown from the material which comes from one nest that a noticeable size difference between the various worker individuals does exist. Also, it was very noticeable that all individuals which still held larvae between the mandibles in death, were small individuals. I also remember that during my observations I noticed particularly that there was a difference of size of the individuals which held the leaves together and of those which acted to defend the nests. It might,

therefore, be possible that such differences are actualities, and I should like to beg future investigators to observe if special individuals have the task (1) of holding the leaves, (2) of weaving with larvae, (3) defense, (4) of collecting honey from aphids. It would be very easily possible that the size differences observed by myself are accidental."

With these accounts brought to light in searching through the scant literature on the subject, it has been thought worthwhile to follow up speculation with actual facts in so far as the preserved material might be utilized. First of

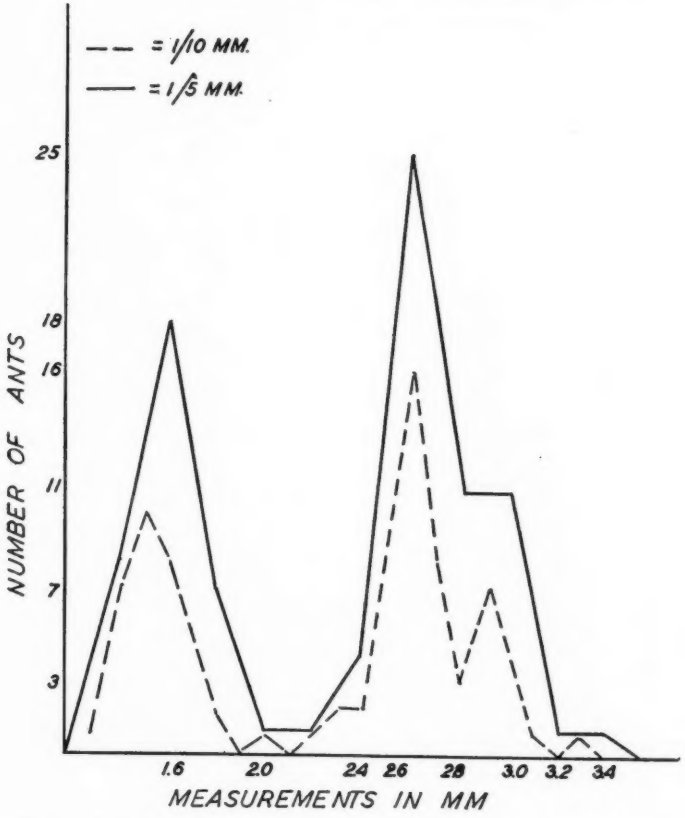

Fig. 4.—Graph showing the bimodal curve obtained from thoracic measurements of 88 ants from NEST 1. The broken line gives a plot when measurements were adjusted to 1/10 mm frequency and the continuous line indicates a plot of the same series adjusted to 1/5 mm. frequency. Actual measurements were made to 1/100 mm.

all, was there actually a dimorphic condition in the workers of *O. smaragdina* and if so were there actual morphological differentiations?

With this view in mind, and following the approach set by Weber (1946) it was decided to measure the random samples of two colonies (one large, the other small) and to see if the apparent size difference was a gradual intergradation representing extremes from a mean average, or to observe if two size groups were involved and, if so, how sharply divided the two "castes" might be. It was apparent that an overall measurement of each ant would not yield an accurate algebraic curve because of variable extensions of the gaster

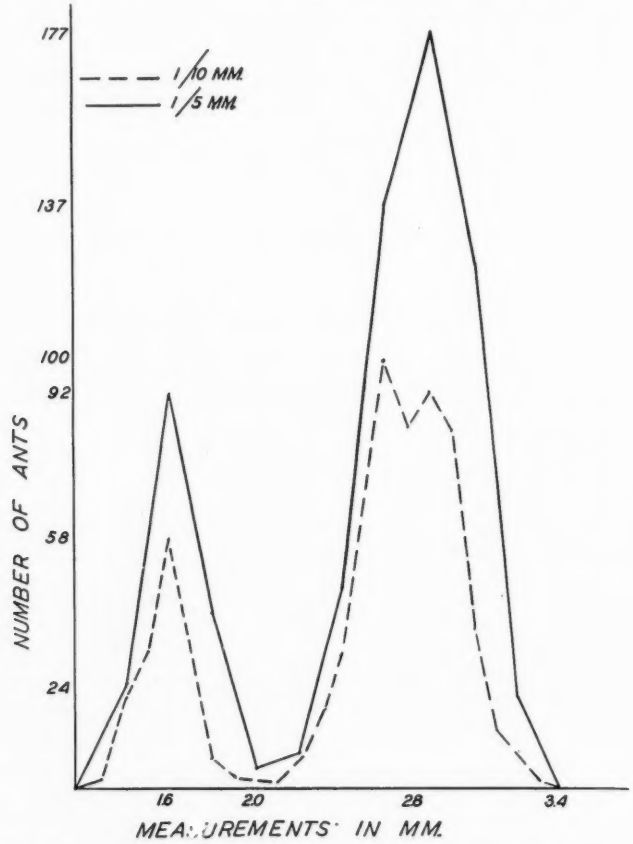

Fig. 5.—Graph showing the bimodal curve obtained from thoracic measurements of 674 ants from Nest 2. These plots are constructed on the same basis as in Fig. 4.

due to preservation. On this basis, a measurement of the overall thorax length was used, since the relative shape and extension of this body region were constant, and an accurate correlation of this length to body length was established.

All specimens were soaked overnight in warm 50% alcohol, becoming somewhat flaccid so that appendages lay in a natural position. Measurements were made by a reticle mounted in a binocular microscope. All measurements were to 1/100 mm. for close accuracy, and translated to the graphs figured. Only workers were used and the results are summarized as follows:

NEST ONE: Of a total of 88 ants from this small nest, measurements gave a very decided bimodal curve which shows two distinct size groups with no overlap. From this nest, 34 ants are represented as minima and 54 as maxima. Extremes for the minima ants are from 1.26 mm. to 1.98 mm. with the greatest frequency lying at 1.50 mm. Maxima extremes are from 2.21 to 3.30 mm. with the greatest frequency at 2.60 mm. The overall extremes for the nest, then, are from 1.26 mm. to 3.30 mm. as far as the thoracic measurements are concerned.

NEST TWO: Of a total of 674 ants taken from this nest, two size groups are shown by a clear bimodal curve. From this nest, 163 ants are represented as minima and 511 as maxima. Extremes for the minima of this nest are from 1.29 mm. to 2.01 mm. with the mode lying at 1.60 mm. Maxima extremes are from 2.16 mm. to 3.30 mm. with the

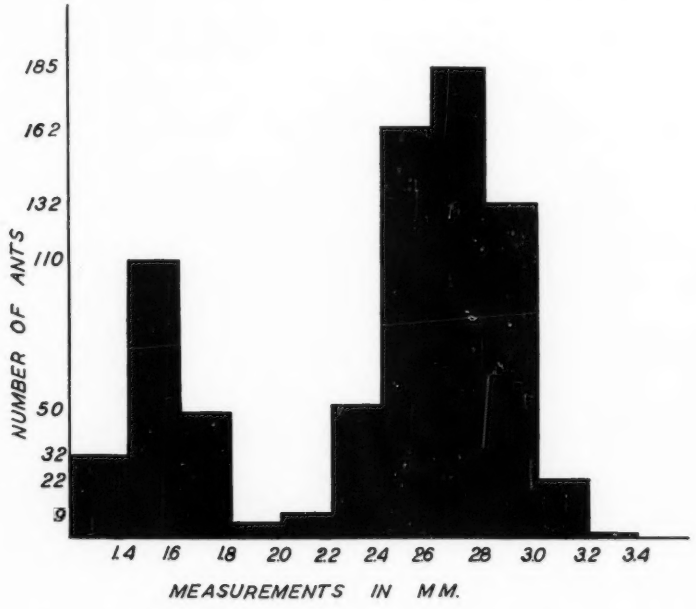

Fig. 6.—A graphic total of all ants measured to show the general trend of the workers of the species.

greatest frequency at 2.65 mm. The overall extremes for individuals of this nest, then, are from 1.29 mm. to 3.30 mm., an essential duplication of size range in nest 1.

Conclusions regarding size range are *indicative*. If, as mentioned, the workers of the species were not dimorphic, one would expect to find, on measurement, a normal frequency curve, the single mode of which would represent the *typical* size and the extremes indicated by the sides of the curve. However, the bimodal curve found in measurements of *O. smaragdina* shows two distinct size groups. An ant of this species selected at random, then, would be either of the maxima series or of the minima series. The variation from the minima mode might be expected to overlap the variation of the maxima mode, but such did not occur in the series to any appreciable extent. Only a single individual fell between the adjacent extremes of the castes and, morphologically, this specimen compared with the minima series. It should also be mentioned, in view of Döflein's observations, that three ants of the minima caste held larvae in their mandibles.

Morphologically, there were found to be certain consistent characteristics which will differentiate one worker caste from the other. Neglecting the very evident size factor, one can correctly state that members of the minima caste are more obviously compact and thickened, whereas the larger caste may be characterized by its long and slender form. The following table lists comparative features of six structures based on actual inspection of twenty-five specimens from each caste:

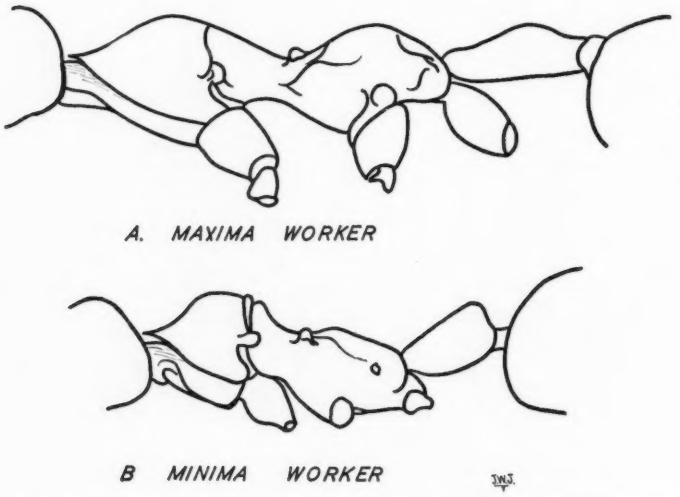

Fig. 7.—Contrasting features of the maxima worker (A) and the minima worker (B) as seen in profile. (Camera lucida drawings from typical specimens.)

	Minima	*Maxima*
Antennal Scape	Never as long as the head, not including the mandibles.	Always as long as or longer than the head including the mandibles.
Clypeus	More convex than in maxima.	Less convex but still not flattened.
Mandibles	Terminal tooth not markedly prominent.	Terminal tooth very prominent.
Pronotum	Spherical: much more convex when viewed in profile.	Longer: not as markedly convex when viewed in profile.
Mesonotum	Not elongated: not cylindrical: tapering uniformly to the posterior margin.	Slender: cylindrical: on the average, three times as long as the constricted width.
Petiole	Never as much as three times as long as thick in profile.	Always at least four times as long as thick as profile.

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A Synopsis of Nevada Orthoptera

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Introduction

As a group, Orthoptera have been collected in Nevada since the earliest days. To my knowledge, the first professionally collected specimens were taken by Robert Ridgway in 1867-1868 while accompanying the Clarence King United States Geological Exploration of the Fortieth Parallel. While primarily interested in ornithology, Ridgway, as survey zoölogist, collected as extensively in many groups of animals as his limited facilities permitted. Peculiarly enough, almost the only records known of Orthoptera taken by Ridgway are from Ruby Valley (Elko County) in northeastern Nevada, although he collected generally from west-central Nevada entirely across the State. As far as the record is concerned, such camps as the Big Bend of the Truckee (river) (July 24—Aug. 18, 1867), Unionville (Oct.), Truckee Meadows (Reno) (Nov. 7-21), Peavine Mountain (Reno) (Nov. 20), Carson City (winter of 1867-1868), Virginia City (June 1868), Austin (July), and various stops between Austin and Ruby Valley, to the east, were largely unproductive of Orthoptera, although the results achieved among vertebrates, particularly birds, were quite noteworthy.

As an indication of the existence of local interest in the new State's natural history, Ridgway warmly mentions an H. G. Parker, of Carson City, then Nevada Superintendent of Indian Affairs, for his direct aid in the collecting of many biological specimens. Through the efforts of Parker, Ridgway was able to visit Anaho Island (the pelican rookery in Pyramid Lake) several times, and made the Peavine trip in his company.

The next orthopterous collections of importance were those made chiefly by Cyrus Thomas, H. W. Henshaw, H. C. Yarrow and W. I. Hoffmann during Lt. George M. Wheeler's United States Army Engineer Surveys of the 100th Meridian in the years 1871 to 1874; most of this material was worked up by Dr. Cyrus Thomas who described many of the specimens as new in his reports of 1873 and 1875. Following this, Dr. A. S. Packard, Jr., one of the country's outstanding entomologists, made a collecting trip through the State in 1877, and sent his Orthoptera to Samuel H. Scudder. Other collectors in subsequent years numbered among them Garman, Palmer, Burrison, S. Henshaw, Morrison, Wickham, Baker, Crotch and H. Edwards.

It was not until the 1890s that residents of the State gave evidence of an interest of their own in Nevada insects. During this decade, Professors E. H. Hillman and Samuel B. Doten (recently retired as Director of the Nevada Agricultural Experiment Station) made extensive collections about Reno, the

former sending large amounts of material to eastern specialists for determination. Prof. Lawrence Bruner of the University of Nebraska received most of Hillman's Orthoptera, and in turn remitted much of it to Dr. Scudder, then the country's leading orthopterist. Unfortunately, these local efforts were largely brought to a standstill by the departure of Hillman and the loss of the young collection in a fire at the University of Nevada. In the quarter-century between 1900 and 1925, Morgan Hebard and J. A. G. Rehn of the Philadelphia Academy of Natural Sciences were the most active orthopterists in Nevada, making numerous and extensive collecting trips, especially through southern Nevada, and accumulating more material than the combined efforts of all previous collectors. From this wealth of specimens have come numerous papers and analyses of the western fauna.,

The interesting Charles F. Baker and his wife collected Orthoptera briefly in the vicinity of Carson City, obtaining material from which Dr. A. P. Morse described four new species, none of which are now in good repute. In November of 1903, five months after the appearance of the Morse descriptions, Baker, in a now little-known publication entitled "Invertebrata Pacifica" from Pomona College, issued what he termed the "First decade of Orthoptera issued in the 'Invertebrata Pacifica' series" in which he gave fuller notes on his Carson City collecting and reprinted Morse's descriptions. Since the publication is now largely a curiosity and difficult to come by, I include his short notes:

"The first decade of Orthoptera now being issued to subscribers contain four new species, Professor Morse's descriptions of which are quoted in this paper. He is also authority for all the determinations. All the material for this first decade was collected in Ormsby county, Nevada, by my wife and myself. We took all these, together with others, in the lower edge of the pine zone west of Carson City, among pine groves and sage brush openings at from 1700 to 2000 metres. This first decade is as follows: 17. **Cordillacris affinis** Morse n. sp., 15. **Stenobothrus acutus** Morse n. sp., 20. **Bruneria shastana** Scud., 310. **Aulocara elliottii** Thos., 307. **Hippiscus neglectus** Thos., 5. **Trimerotropis juliana** Scudd., 6. **Trimerotropis bifasciata** Mc N., 18. **Hesperotettix Nevadensis** Morse n. sp., 19. **Oedaleonotus enigma** Scudd., 24. **Bradynotes compacta** Morse n. sp.

"Of these No 310 was abundant, Nos. 6, 307 and 19 were fairly common. Nos. 17, 15, 20, 5 and 18 were infrequent and local. Perhaps the most interesting species is No. 24, the new *Bradynotes*. This was found common in the sage brush after we became familiar with its habits. It is wingless and a poor jumper, but expert at 'playing possum.' When the bush is jarred it drops at once and lies on the ground with legs folded against the body. In this condition it is very difficult to find."

A few lines down the same page, under the new title, "Additional notes on Pacific Coast Orthoptera," Baker adds:

"Besides the Nevada species to be issued in the first decade, there were also collected in the same locality" (Carson City) "*Camnula pellucida* Scudd.,

very common; one of the 'Jerusalem Crickets,' *Cacopteris inermis* Scudd. common; *Trimerotropis fallax* Sauss., and *Xiphidium occidentale* Morse, occasional; under boards, logs, and stones the curious *Stenopalmatus longispina* Brunn., occurred frequently. Some of the Nevada Melanopli are still undetermined."

Each year since 1920 has seen an increase in casual collecting of Nevada material by eastern entomologists. In 1935 I began collecting Orthoptera, chiefly in the vicinity of Reno, gradually expanding these efforts as the completion of basic Coleoptera collecting made such possible. This small collection still leaves much to be desired, and forms only a portion of this report, much of which is necessarily based on records already in the literature.

The Orthoptera of the State are still insufficiently known to allow of comprehensive zonal and ecologic discussions, but certain outstanding environmental situations are worthy of noting. One of the most prominent of such areas is the *Sonoran Trailway,* a biologic route physiographically indefinite, but of concrete importance biologically, extending from regions to the south up into western Nevada (probably into eastern Nevada as well, although it is less perfectly known here), ending in the vicinity of Pyramid Lake and crossing Nye, Esmeralda, Mineral, Lyon, Storey and Washoe Counties. Animals of many phyla have entered Nevada from the subtropical regions to the south, and penetrated deep into the State through a series of narrow, north-south striking valleys directly connecting the southern "Lower Sonoran Zone," with the *Artemisia* areas predominant over northern Nevada. Among the most noticeable of these emigrant species are the lizards *Callisaurus draconoides* and *Sceloporus magister;* several species of the mammalian genus *Dipodomys;* the tenebrionids *Eleodes armata, E. grandicollis* and *Cryptoglossa verrucosa;* the carabid *Calosoma parvicollis;* and the locustid *Ligurotettix coquilletti.*

The second distinctive ecologic factor is that area encompassed by the ancient boundaries of Pleistocene Lake Lahontan, a body of water once occupying vast areas of west-central and northern Nevada. Unlike its contemporary, Lake Bonneville in Utah, which largely presented the facies of a broad sheet of water, Lake Lahontan was confined between Nevada's parallel mountain ranges into long, narrow bays, the most prominent of which were those portions occupying the long, winding valley of the Humboldt, and that just to the west, now characterized by the great alkali flats known as the Black Rock, Smoke Creek and Winnemucca Sinks (or Deserts) and Pyramid Lake. In the last generation of its existence, the lake rose to its greatest heights, overflowed areas to the south, and finally included Walker Lake as its southernmost extension. Thus, the last (southern) 100 miles of Lahontan is now the northern portion of the *Sonoran Trailway,* and forms a direct link between the Trailway and the extensive Humboldt system penetrating diagonally across north-central Nevada nearly to the Idaho boundary. Lahontan is the name applied of necessity only to the last body of water to occupy the basin for any length of time—it is certain, in line with evidences of climatic fluctuation from other sources, that there has been more than one inland sea in the gen-

eral area, each separated by periods of varying aridity during which standing bodies of water may have largely disappeared from the Great Basin. That this happened during the existence of Lahontan has been pretty well demonstrated. In terms of long-range speciation, it is the total effect of all waters which have occupied these basins, probably since the Upper Miocene, which is important, and not that of Lahontan alone, which in itself is probably of negligible importance except to its immediate hydrophile populations.

The third area of ecologic importance is composed of the isolated mountain blocks which show very evidently the effects of segregation on their inhabitants. Prominent among these are the Charleston Peak area of the Spring Mountains in southern Nevada, the Wheeler Peak region of eastern Nevada, the Toyabes in central Nevada, and the Ruby Mountains in northeastern Nevada. Only Charleston Peak has been semi-adequately worked, the remainder awaiting the necessary field work.

The complex interplay of species in these areas of flux is still far from satisfactorily understood, and many years of collecting will be needed before the problem is comprehensively resolved. My collecting in these regions has demonstrated that, among animals, the Coleoptera are perhaps the best index to a solution of the problem, but all animals found here are part of the complex, and Orthoptera promise to be of considerable importance in working out details of speciation and distribution.

The overall ecologic picture in Nevada is that of a desert in the usually-accepted sense of the word. Due to the general north-south strike of narrow grabens and horsts so characteristic of the Basin Range structure, great topographic irregularities are produced which in turn complicate the zonational picture over what it would be when ideally-plotted on a flat expanse. As a consequence, adjacent areas of each accepted "zone" are seldom continuous, those occupying lower elevations generally appearing, when mapped, as a series of long fingers or embayments separated from each other by intervening fingers or islands which have, since the initial Miocene disturbance, long since ceased to have any direct contact with each other. As a consequence, fauna and flora with tolerance ranges restricting them to any of these "zones" usually show the effects of this long isolation by the extent of their biotypic segregation, and as such, are more-or-less classical examples of this type of speciation.

What is needed at the present time is some competent attempt to define and standardize nomenclature referring to both deserts in general and the Great Basin in particular, for, unfortunately, both terms have been used with such widely-variant meanings as to be difficult of interpretation when found in a general discussion. True deserts, of course, are regions lacking, for the most part, both flora and fauna. Obviously, an area without a flora will likewise have no fauna except an occasional accidentally-adventive species. Such regions as Sahara and Gobi are true geomorphologic deserts; however, areas such as our western United States intermontane ranges and valleys, while accepted as deserts by laymen and students alike, are far from being true deserts.

A collector of natural history material who has worked our "deserts" cannot fail to have been impressed with the enormous numbers of both plants and animals living there. In many instances, specialized knowledge of, and sound familiarity with, their life histories is necessary before much of this material can be unearthed, and to the casual observer, regions such as the Great Basin seem deserts indeed, for much of their fauna is not conspicuous. On the other hand, a general entomologic collector can accumulate a good representation of the common species of desert insects in less time than a comparable collection can be made in more humid, non-"desert" areas. Such facts render the term "desert," as commonly used, extremely objectionable, but at the present time, there seems to exist no logical substitute.

As regards the term "Great Basin," it has been used for an area as small (approximately) as the State of Nevada, and as large as the entire region between the Rocky Mountains and the Sierra-Cascade chain, from British Columbia south into northwestern Mexico, and for several intermediate combinations. In its strictest sense, "Great Basin" refers logically to that area of interior drainage between the Sierra Nevada mountains and the Wasatch range which has no outlet to the sea. Thus, all of Nevada lies within the Great Basin except a small portion of the northeast corner which drains, via the Owyhee, Bruneau and Jarbridge rivers, to the Pacific through the Snake-Columbia system, and an even smaller region in the extreme southeastern tip tributary to the Rio Colorado through the Moapa and Virgin rivers. Large areas of western Utah also qualify, as do small sections of Oregon, Idaho and southeastern California. Such a definition is strictly a geomorphologic one. Other uses of the term "Great Basin" delineate it entirely on the basis of flora and fauna, particularly the former, and as such, arbitrary lines are drawn where no actual barrier exists, such as designating the junction of "Lower" and "Upper Sonoran" zones by the presence, or absence, of the creosote bush, etc. While it is patent that the environment, particularly in one such as the broken topography of the Great Basin where gradient potentials are often steep and abrupt, may largely govern the distribution of flora and fauna by functioning through their specific tolerances to temperatures, humidities, edaphic factors, etc., it is also quite obvious, I believe, that the terms "Great Basin" as used by the physiographer and the naturalist are largely incompatible, since they are used in entirely different senses and based on unrelated concepts. It would seem desirable, therefore, to standardize the geomorphologic concept of the Great Basin, and, to avoid confusion in the general use of the term, to indicate by complementary terminology the various floral and/or faunal units designated within the physiographic province. Here again, strict standardization is sorely-needed, since many students have selected different plants and/or animals as type indicators of the same general biotic region, which consequently has suffered corresponding fluctuations in total area. For similar reasons, such terms as "Lower" and "Upper Sonoran" are ambiguous in that they are obviously only second-hand attempts to manufacture abstractions from type indicators. In this instance, much more clarity would be obtained by using the indicators themselves to name the "zone" (as

has often been done), and it would eliminate unnecessary elements from the ecologist's verbal repertoire, which has long suffered from cancer of the vocabularly. Thus, since creosote and sagebrush are accepted by all students as type indicators of their respective zones, I have felt it unnecessary in the following account to resort to antiquated terms such as "Lower Sonoran," which merely beg-the-question.

With respect to the Great Basin proper (which in this report will be considered in the strictest physiographic concept as that area lacking in external drainage), one prominent fallacy regarding the distribution of indicator plants should be clarified. Many authors have discussed the floral assemblage and while aware of the presence of *Atriplex* and *Sarcobatus* in the "Upper Sonoran" or "Sagebrush Zone," have persisted in ignoring these plants as major type indicators, and have perpetuated the misconception that sagebrush is the dominant plant. Dr. W. D. Billings, of the University of Nevada, has worked out the distribution of this intermediate zone in detail as it occurs in Nevada, and has already published some aspects of the total zonational picture as altered by the existence of this additional associational pattern, although his main report is still unpublished. A published abstract of his findings is reproduced below in which all salient details are brought out:

"Clements' basin sagebrush association of the sagebrush formation consists in reality of two distinct associations: the sagebrush association dominated by *Artemisia tridentata* and the shadscale association dominated primarily by *Atriplex confertifolia* and *Artemisia spinescens*. The shadscale association, almost as extensive as the sagebrush association, is climax in the drier parts of the formation where the annual precipitation is generally below 6 or 7 inches. In the northern arm of the Basin-and-Range Province, it forms a distinct zone between the sagebrush association on the north and the creosote bush association of the desert scrub formation on the south. In the climax condition, the shadscale association extends from the mountain ranges surrounding Death Valley northward through the arid trough east of the Sierra Nevada to western and north-central Nevada (Billings, 1945). The climax shadscale zone is present also in the deserts of western Utah (Fautin, 1946) and, perhaps, in the Green River drainage of eastern Utah (Graham, 1937). Heretofore, the shadscale association has been mentioned usually in connection with dry lowland soils possessing a degree of salinity in the subsoil. This is generally true at its northern and eastern extremities but throughout much of its range, it is a climatic climax on residual or transported gray-desert soils which are usually marked by a pronounced desert pavement" (1947).

In its simplest terms, a concise practical zonation picture is achieved by considering these floral elements as representative of three separate entities, viz., SAGEBRUSH ZONE (indicator *Artemisia tridentata*), SHADSCALE ZONE (indicators *Atriplex confertifolia* and *Artemisia spinescens*) and CREOSOTE ZONE (indicator *Larrea divaricata*), which characterizations will be used in this report.

Since considerable emphasis will be placed upon the Lahontan Basin occur-

rence of certain key Orthoptera, it may be well to recall some of Dr. Billing's 1945 characterizations of the Basin:

"Most of the region was covered during the pluvial and glacial periods of the Pleistocene by the southern part of Lake Lahontan. Russell (1885) gives 4,378 feet above sea-level as the average elevation of the highest shoreline of this lake. Lake-laid sediments now cover almost all of the Carson Desert region" (which roughly corresponds to the southern half of the Lahontan Basin) "below this elevation. They consist primarily of interbedded gravels, clays, and sands whose depth ranges from a few inches near the upper limits of the lake to well over a hundred feet in many places. Two types of post-Lahontan accumulations overlie the old lake sediments in a number of places. The first of these consists of aeolian sands of a light color and, therefore, clearly of extraneous origin in this region of dark volcanic rocks. Many of these dunes are active but the great majority are flat and quiescent and covered with a distinctive vegetation. Mud flats or playas constitute the second kind of post-Lahontan sediment. The lower parts of those rift basins not occupied at present by permanent lakes are filled during winters and wet years with shallow temporary lakes. Silts, clays, and salts carried into these playa-lakes are left behind upon the evaporation of the water during the summer months. Because of salinity and periodic drowning, most of the playas are completely devoid of vegetation except around the edges."

I am inclined to believe that the numerous aeolian sands, as mentioned above, which are so important as specific habitats for certain Orthoptera—as well as plants and other insects—are derived from the Basin itself, and not of foreign origin as Dr. Billings suggests; there are many granitic outcrops spotted inconspicuously about the Basin and dark igneous rocks themselves are sand-producers.

To further clarify orthopteral distribution in Nevada in relation to the total zonal picture, enough data is at hand to construct tentative lists of species representative of the various floral associations, as below:

SAGEBRUSH ZONE: *Amphitornus coloradus, Ageneotettix deorum, Camnula pellucida, Xanthippus corallipes, X. lateritius, Cratypedes neglectus, Trimerotropis suffusa fallax, Hesperotettix viridis, Melanoplus bivittatus, Bradynotes obesa, B. pinguis, Anabrus simplex, Idiostatus elegans, I. inermis, I. nevadensis, Stenopelmatus fuscus, Pristoceuthophilus pacificus* and *Parcoblatta americana.*

SHADSCALE ZONE: *Orphulella pelidna, Trimerotropis strenua, Anconia caeruleipennis, Coniana snowi, Zacycloptera atripennis, Plagiostira gillettei, Ceuthophilus fossor* and *Ammobaenetes lariversi.*

CREOSOTE ZONE: *Orphulella compta, Tytthotyle maculata, Insara covillеae, I. brevicauda, Neoconocephalus triops, Cycloptilum comprehendens, Miogryllus lineatus, Nemobius cubensis* and *Arenivaga apacha.*

SAGEBRUSH-SHADSCALE ZONES: *Conozoa wallula, Trimerotropis rebellis, T. caeruleipennis, T. laticincta, T. fontana, Circotettix carlinianus, Melano-*

plus mexicanus, M. occidentalis, M. complanatipes, M. packardi, Capnobotes occidentalis, Œcanthus niveus and *Parabacillus hesperus.*

SHADSCALE-CREOSOTE ZONES: *Ligurotettix coquilletti, Conozoa sulcifrons, Xeracris parviceps, Arethaea coyotero* and *Arenivaga erratica.*

SAGEBRUSH-SHADSCALE-CREOSOTE ZONES: *Aulocara elliotti, Trimerotropis albescens, T. pallidipennis, Capnobotes fuliginosus* and *Litaneutria minor.*

The following species are zonationally-erratic since they depend upon the vicinity of water and agricultural areas for optimum habitats in Nevada, although they are in no sense even semi-aquatic: *Dissosteira carolina, Arphia pseudonietana, Schistocerca shoshone, Melanoplus femur-rubrum* and *Conocephalus fasciatus.*

The above listings show the major distributional fasciations among Orthoptera as far as our present limited knowledge of the State permits their delineation. Future work will undoubtedly alter the picture somewhat.

ACKNOWLEDGMENT

I would here like to acknowledge my indebtedness to Dr. H. F. Strohecker for determining the great majority of my Orthoptera, and for his generosity in checking over a draft of the manuscript for synonymies and additions. Any errors remaining will have their source in material added since his perusal. I would like to express my appreciation to Dr. Billings for his constructive clarification of my own limited concept of the zonal picture in Nevada. His basic work in Great Basin botanical ecology will be appreciated by all who have occasion to work with either plants or animals in the region. Dr. E. C. Van Dyke very kindly extended the facilities of the California Academy of Sciences' entomology department, and Mr. Theodore O. Thatcher generously contributed Orthoptera records from the vicinity of Baker, in eastern Nevada. Mr. Urless N. Lanham has also added some eastern Nevada records. Under the species concerned, I have listed by their last names, for the sake of brevity, various colleagues who have collected with me over the State in the past. To acknowledge their cooperation, and for the sake of the record, I append their full names: Thomas J. Trelease and Newell Hancock of Sparks, and Glen C. Christensen, Charles C. Gibson and James A. Mahoney of Reno.

Systematic

While my primary interest has been in the Coleoptera, it is impossible to collect over a typical desert area without immediately becoming impressed with the fact that Orthoptera are generally the most characteristically conspicuous of all insects encountered in these arid regions; particularly noticeable are such noisy and beautiful fliers as the *Trimerotropis-Circotettix* group, inhabitants of Sagebrush- and Shadscale Zones; *Arphias*, found from some of the few lush meadows of the State to poplar-shaded desert riverbottoms; the drab but omnipresent *Melanopli;* and the destructive tettigoniids, *Anabrus* and *Idiostatus*, the former often occurring in countless millions in northern Nevada and posing a serious economic problem. Many of the smaller and less conspicuous groups are equally interesting, although much less well-known.

In the following account, keys are provided to the generic level. It is not feasible, with our present knowledge, to attempt tables to *Trimerotropis*, while such groups as *Melanoplus* need to be illustrated for proper understanding of each species. In the interests of conformity, therefore, no specific keys are included. However, of the 140 species listed, nearly 40%, being the only

species known from the State in their respective genera, can be satisfactorily placed.

Keys have been drawn from many sources; Ball et al. (1942) has been extensively used, and other sources are acknowledged where they appear in the text.

Order ORTHOPTERA

THE SUBORDERS OF ORTHOPTERA KNOWN TO OCCUR IN NEVADA

1. Tarsi less than 5-segmented; hind legs elongated, adapted for jumping ..... (locusts, grasshoppers, crickets) LOCUSTODEA
—Tarsi 5-segmented; hind legs not elongated or adapted for jumping 2
2. Pronotum wide and shield-like, concealing most of head .....(roaches) BLATTODEA
—Pronotum narrow, not covering head, which is free 3
3. Eyes proportionately large; forelegs dilated and spinuous, adapted for seizing prey ..... (manteids) MANTEODEA
—Eyes small; forelegs normal; body thin, attenuate .....(walking sticks) PHASMODEA

Suborder LOCUSTODEA

THE SUPERFAMILIES OF LOCUSTODEA KNOWN TO OCCUR IN NEVADA

Mesotarsi 3-segmented; ovipositor never elongate; antennae shorter than body with less than 30 segments; if present, auditory organs situated near base of abdomen .....(grouselocusts, locusts, grasshoppers) LOCUSTOIDEA
Mesotarsi 4- or 3-segmented; ovipositor noticeably elongated into a sword- or needle-like organ; antennae longer than body; if present, auditory organ situated on protibiae .....(katydids, crickets) TETTIGONIOIDEA

Superfamily LOCUSTOIDEA

THE FAMILIES OF LOCUSTOIDEA KNOWN TO OCCUR IN NEVADA

Pronotum greatly elongated posteriorly, covering all or nearly all, of abdomen..... (pygmy- or grouselocusts) ACRYDIIDAE
Pronotum at most covering only the basal abdominal segments ..... (locusts, grasshoppers) LOCUSTIDAE

Family ACRYDIIDAE (*Tetrigidae, Tettigidae*)

THE GENERA (AND SPECIES) OF ACRYDIIDAE KNOWN TO OCCUR IN NEVADA

From dorsal aspect, fastigium (especially its carina) produced beyond eyes anteriad; fastigium considerably wider than either eye .....*Acrydium subulatum*
From dorsal aspect, fastigium (with carina) not produced beyond eyes anteriad; fastigium narrower than either eye (♂♂) or slightly wider (♀♀) ..... *Paratettix cucullatus extensus*

This small but interesting family is weakly represented in the portions of Nevada collected over. I have taken them only about Reno, and they have been recorded from the vicinity of Las Vegas; doubtless they occur in some of the other humid areas of the State. The arthropod fauna about Reno is not typically an arid one, although possessed of many desert intrusives, since the town is situated in a well-watered valley (Truckee Meadows) lying along the eastern face of the lofty and humid Sierra Nevada mountains, separating Nevada and California. It is in such an environment that acrydiids are to be sought.

1. PARATETTIX CUCULLATUS EXTENSUS Morse 1899 (*P. morsei* Hancock 1902, *P. robustus* Hancock 1902).

WASHOE COUNTY (*Reno* (Truckee Meadows) 2/V/40, 2/VI/40, 8/VI/41, el. 4500 ft. –LaR).

As *P. toltecus* (Saussure) 1861, Rehn and Hebard (1909B) recorded the first Nevada acrydiids from "Las Vegas, August 10, in a grassy well-watered strip along a stream" (Clark County, at that time Lincoln County) a few miles north of the city. *P. toltecus* has been relegated to the synonymy of *P. c. mexicanus* (Saussure) 1861 by Hebard (1935B), a race typical of eastern Mexico, and all Nevada records of *Paratettix* now fall to *extensus*.

2. ACRYDIUM SUBULATUM (Linnaeus) 1761 (*Tetrix, Tettix*)

DOUGLAS COUNTY (*Lake Tahoe* 20/VI/40, el. 6300 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 18/III/40, 2/VI/40, 18/V/41, el. 4500 ft. –LaR)

This trim, tan species is an habitué of meadows bordering ponds and streams and occurs throughout the spring, summer and fall seasons.

Family LOCUSTIDAE (*Acrididae, Acridiidae*)

THE SUBFAMILIES OF LOCUSTIDAE KNOWN TO OCCUR IN NEVADA

1. Prosternum bearing a conspicuous conical or cylindrical spine ..... Cyrtacanthacrinae
—Prosternum without such a spine 2
2. Antennae shorter than profemora ..... Eumastacinae
—Antennae longer than profemora 3
3. Metatibiae with three apical external spines ..... Romaleinae
—Metatibiae with two apical external spines 4
4. Hind wings usually banded and/or highly colored; median carina of pronotum usually raised crest-like above the dorsal field of the pronotum; face usually vertical or nearly so when viewed laterad, usually forming a rounded juncture with the vertex ..... Oedipodinae
—Hind wings never banded or colored; median pronotal carina threadlike; face usually slanting markedly backward from vertex to mouthparts when viewed laterad, usually forming a distinctly acute angle with the vertex ..... Locustinae

Subfamily EUMASTACINAE

THE GENERA (AND SPECIES) OF EUMASTACINAE KNOWN, OR LIKELY TO OCCUR, IN NEVADA
(adapted from Hebard 1934A)

1. Antennae with 10th segment toothed disto-ventrad; ♂♂ cerci falcate, subgenital plate with a linguliform process in its meso-dorsal section (metafemora with apex armed with a medio-dorsal and dorso-lateral minute teeth, as are the genicular lobes) ..... *Morsea californica dumicola*
—Antennae with 9th segment tooth disto-ventrad; ♂♂ cerci simple, styliform; subgenital plate lacking a linguliform process in its meso-dorsal section 2
2. Metaforma with apex armed with a medio-dorsal and dorso-lateral minute teeth, as are the genicular lobes; (in *P. psylla robusta* these teeth may be absent at the externo-dorsal point and on the external genicular lobes); tarsal claws symmetrical; form robust; fastigium at most but slightly projecting anteriad of eyes ..... *Psychomastax psylla robusta*
—Metafemora with apex armed with only a medio-dorsal minute tooth and genicular lobes unarmed; tarsal claws highly asymmetrical; form slender; fastigium strongly projecting anteriad of the eyes ..... (*Eumorsea*)

3. MORSEA CALIFORNICA DUMICOLA Rehn & Hebard 1918

LINCOLN COUNTY (*Caliente* 3/IX/09, el. 4400-5200 ft. –R & H; *Crestline* 4/IX/09, el. 5900-6000 ft. –R & H) (Rehn and Hebard 1918). I have no specimens.

Rehn and Hebard (1918) wrote of this: "The eastern race occurs at localities in the Upper Sonoran Zone in southeastern Nevada and in central Arizona; in the Meadow Valley and Juniper mountains regions of Lincoln County in the former state, and the Prescott region of Yavapai County in the latter one. It is quite probable it will be found in suitable environments in the intervening country, as conditions at one of the Nevada localities (Crestline) were very similar to those found on the Coconino Plateau region of northern Arizona.

"This race is as thamnophilous as the others of this species. At Caliente it occurred on several bushes, one of which was *Kunzia tridentata*, on mountain slopes rising from a wash of Meadow Valley, while at Crestline it was quite numerous on the same bush growing in open stands of Utah Juniper (*Juniperus utahensis*) and occasional pinyon (*Pinus monophylla*) on the rolling plateau summit of the Juniper Mountains."

4. PSYCHOMASTAX PSYLLA ROBUSTA Hebard 1934

CLARK COUNTY (*Charleston Peak* (Spring Range) 19/VIII/19, el. 10,200 ft. –Hebard; 14/VIII/31, el. 9000-11,400 ft. –E. R. Tinkham; *Lee Cañon* (Spring Range) 18/VIII/19, el. 6000 ft. –Rehn); NYE COUNTY (*Belted Peak* 25/VIII/24, el. 6700 ft. –Hebard) (Hebard 1934A). The type locality of *robusta* is at 10,200 feet, Charleston Peak. I have no specimens.

Hebard (1934A) records the species from juniper, pinon, and gooseberry, and from the vicinity of *Pinus ponderosa* and *P. aristata* on Charleston Peak.

Subfamily LOCUSTINAE (*Acridinae, Acridiinae, Tryxalinae, Truxalinae*)

THE GENERA OF LOCUSTINAE KNOWN, OR LIKELY TO OCCUR, IN NEVADA

1. Lateral foveolae of vertex forming a right or acute angle with plane of the fastigium and invisible dorsad; face usually strongly slanting backward, forming an acute angle at its meeting with the vertex 2
—Lateral foveolae forming an obtuse angle with the fastigium and visible dorsad; face usually vertical and rounded at meeting with vertex 14
2. Lateral carinae of pronotum straight; antennae strongly sword-shaped 3
—Carinae curved; antennae round or slightly flattened 5
3. Antennae short, apical half flattened only slightly; form robust ..... (*Opeia*)
—Antennae very long, flattened for entire length; form slender 4
4. Forewings broadly rounded at apex ..... *Mermiria*
—Forewings pointed at apex ..... (*Achurum*)
5. Pronotum saddle-shaped; head distinclty elevated above the pronotum 6
—Pronotum normal; head not distinctly elevated above pronotum 7
6. Hind wings marked with black; body color brown or green ..... *Pedioscirtetes*
—Hind wings colorless; body color green with white and brown markings ..... *Boöttettix*
7. Wings not extending past end of abdomen 8
—Wings longer than abdomen 9
8. Forewings greenish, marked with four dark patches; face rounded and nearly vertical; robust ..... (*Phlibostroma*)
—Forewings brown; face slanting; slender ..... (*Neopodismopsis*)
9. Median carina distnict; vertex fastigium convex, lacking a conspicuous impression..10

—Median carina indistinct; vertex fastigium flat or concave, with a conspicuous impression 13

10. Internal apical spurs of hind tibiae unequal; antennae slightly flattened and slightly broader near apex ..... (*Eritettix*)

—Internal spurs equal; antennae rounded or tapering gradually to apex 11

11. Hind tibiae with 15-24 external spines; ♀♀ large, robust; ♂♂ small, slender ..... (*Syrbula*)

—Hind tibiae with 12-15 spines; slender 12

12. Lateral pronotal carinae indistinct and curved; body color brown, striped with cream ..... *Amphitornus*

—Carinae distinct and nearly straight; brown ..... (*Amblytropidia*)

13. Antennae round; lateral pronotal carinae distinct; body color brown or green ..... *Orphulella*

—Antennae slightly sword-shaped; carinae indistinct except in color; body color brown ..... *Cordillacris*

14. Lateral pronotal carinae absent; costal field of forewing expanded; bush-inhabiting species; pronotum saddle-shaped ..... *Ligurotettix*

—Carinae present; costal field normal; ground inhabiting; pronotum normal 15

15. Antennae flattened 16

—Antennae simple 18

16. Antennae club-shaped ..... (*Acropedellus*)

—Antennae sword-shaped 17

17. Antennae normal in length; pronotal lateral carinae angularly constricted; pronotal sides brown with a pale stripe on the lower border ..... (*Horesidotes*)

—Antennae very long; carinae curved; pronotal sides with narrow brown stripe ..... (*Acantherus*)

18. Face slanting, meeting the vertex at an angle; inner apical spurs of metatibiae nearly equal in length; wings shorter than abdomen ..... *Chorthippus*

—Face nearly vertical when viewed laterad, and rounded at meeting with vertex; wings long or short 19

19. Median pronotal carina obsolete for most of its length ..... (*Heliaula*) 20

20. Median pronotal carina low on the metazone and cut by two sulci; metatibiae blue 21

—Carina percurrent and cut by one sulcus; metatibiae red or tan 22

21. Wings shorter than abdomen ..... (*Drepanopterna*)

—Wings longer than abdomen ..... *Aulocara*

22. Lateral vertex foveolae indistinct; size large 23

—Foveolae distinct and well-marked; small 25

23. Wings longer than abdomen; metatibiae brown ..... (*Rhammatocerus*)

—Wings shorter than abdomen; metatibiae red or black 24

24. Lateral vertex carinae present; metafemora conspicuously banded ..... (*Morseiella*)

—Vertex evenly rounded; metafemora with pale bands ..... (*Boöpedon*)

25. Prozone shorter than metazone; lateral pronotal carinae percurrent and sharply constricted in middle; metatibiae buff or pink ..... *Psoloessa*

—Prozone longer than metazone; carinae obsolete on prozone; metatibiae red 26

26. Fastigial apex rounded ..... *Agenetettix*

—Fastigial apex subacute ..... (*Zapata*)

5. MERMIRIA MACULIPENNIS Bruner 1890

CLARK COUNTY (*Rioville*, 2/1/91 (U.S.N.M.)) (Rehn 1919).

In a footnote, Rehn (1919) stated that this locality was "erroneously given as Risville by McNeill, on the basis of the same material." I have no specimens.

6. BOOTETTIX PUNCTATUS (Scudder) 1890 (*Gymnes*)

Rehn and Hebard (1909) recorded this species from the "foothills Bird Spring Mountains, California and Nevada, August 11 3 ♂" (McCullough Range, Clark County.) I have no specimens.

7. PEDIOSCIRTETES NEVADENSIS Thomas 1873 (also *Pedioscertetes*)

Thomas described this species from material collected during the 1871 Wheeler Geographical Surveys in Nevada. Specimens came from the region between Carlin in northern Nevada and Cottonwood in northwestern Arizona. Apparently the collections were lumped together without segregating labels, but Thomas thinks the specimens of *P. nevadensis* must have come from the "extreme southwestern limit of the second expedition" in southern Nevada. I do not have the species.

8. AMPHITORNUS COLORADUS ORNATUS McNeill 1897 (*A. unicolor* (McNeill) 1897, *A. carinatus* (Scudder) 1899; *Akentetus, Stenobothrus*)

LYON COUNTY (*Yerington* 28/VIII/46, el. 4400 ft. –LaR); MINERAL COUNTY (near *Lucky Boy Mine* (Hawthorne) 5/IX/46, el. 5500 ft. –LaR & Gibson); WASHOE COUNTY (*Reno* (Truckee Meadows) 1/VIII/40, el. 4500 ft. –LaR).

A quite common, striped, point-headed species found in meadows and adjacent to rivers, as well as at moderate-to-high altitudes in desert ranges. Hebard (1937) recorded *ornatus* from the Egan Range near Ely (White Pine County) at 8000 feet. At the Lucky Boy Mine locality, *A. c. ornatus* was associated with a large population of *Trimerotropis caeruleipennis* and *T. albescens*, and was confined to a sparse reed-like growth along the dry cañon streambed.

—AMPHITORNUS COLORADUS SALTATOR Hebard 1937

WHITE PINE COUNTY (vicinity of *Connors Pass* (Schell Creek Range) 28-31/IX/24, el. 7900-8100 ft. –Rehn & Hebard) (Hebard 1937). I have no specimens.

Some of Hebard's (1937) observations when describing this form are pertinent: "Were it not for the uniformity shown in the reduction in the organs of flight in several widely-separated areas, indicating stability in this feature in similar environment over a considerable extent of territory, I would not consider recognizing the present condition as a race. In the valleys and generally at lower elevation over the region where *coloradus saltator* is found no material of the species has been taken. If the species exists there it will be of interest to discover which race is represented. From the Beaver" (Utah) "specimens, however, even closer approach to *coloradus ornatus* is suggested for individuals from still lower elevations.

"In summarizing I would state that *coloradus saltator* is a development of the western race *coloradus ornatus* occurring typical only over an area lying in the southeastern portion of the Basin and Range Province, there present only at the higher elevations at which the species can exist. In this region (south and west of the Wasatch Mountains in Utah west to the Shell Creek

Range in Nevada) even in the least sterile lower areas the species has not been found. From the Wasatch Mountains in Utah, southern Idaho, Nevada south and west of the Egan Range to Crestline, only *coloradus ornatus* is present both in the mountains and the valleys." Collecting notes included "in fine dry yellow grass where this was thickest in the draws; . . . very scarce in tufts of fine yellow grass on mountain slopes in opening of juniper area with some piñon."

9. CORDILLACRIS OCCIPITALIS CINEREA (Bruner) 1889 (*C. affinis* Morse 1903; *Alpha, Ochrilidia?*)

HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 31(VII)46, el. 4800 ft. –LaR); MINERAL COUNTY (*Thorne dune* 7(VII)41, el. 4600 ft. –LaR & Christensen); ORMSBY COUNTY (*Carson City* 12(IX)39, el. 4650 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 24(VIII)41, el. 4500 ft. –LaR).

Morse described *affinis* from several specimens collected by Prof. Charles F. Baker in "Ormsby Co., Nev., July 6." Fortunately, Ormsby County is an exceedingly small area, and my specimens from Carson City can be regarded as topotypic and indicate the above synonymy. At the Paradise Valley locality, the species was common feeding and resting in clumps of the very numerous sand bunchgrass *Oryzopsis hymenoides*. In 1906, Rehn reported *affinis* from Utah. The species has been found as high as 8000 feet in the Colorado Rockies (Hebard 1928).

10. ORPHULELLA COMPTA Scudder 1899. (*O. affinis* Scudder 1889, *O. graminea* Bruner 1904)

CLARK COUNTY (*Las Vegas* 10/VIII/07, el. 2050 ft. –Rehn & Hebard) (Rehn and Hebard 1909B). I have no specimens.

Rehn and Hebard (1909B) noted: "At Las Vegas the species was found well distributed in grass beside a stream." In 1938, Tinkham, in a list of Orthoptera caught at night wrote: "Las Vegas, 31/VII/30, E. R. Tinkham, fairly common at night." Gurney (1940) listed the additional localities of Bunkerville, Logandale and Mesquite in Clark County.

In Nevada, *O. compta* is restricted to the Creosote Zone and is replaced to the north by *O. pelidna desereta*. It occurs in greatest abundance about desert waterholes, streams and in irrigated areas—so much so as to seem one of the most characteristic species of such environments. In Arizona, it has been recorded from grasses of the genera *Distichlis* and *Sporobolus* (Ball et al. 1942).

11. ORPHULELLA PELIDNA DESERETA Scudder 1899 (*O. salina* Scudder 1899)

LINCOLN COUNTY (*Hiko* 12/VIII/40, el. 3800 ft. –LaR).

Gurney (1940) gives the Nevada distribution as: "Darroughs Hot Springs (Big Smoky Valley, Nye County), Clover Valley (Elko County)." It is also known from Amedee, just across the line into California, so undoubtedly occurs in adjacent areas of west-central Nevada also, indicating its occurrence over the entire State in suitable habitats. From known records, this

species seems confined, in Nevada, to the Shadscale Zone, although it apparently overlaps into the Sagebrush Zone in adjacent States. Like *O. compta*, this species exhibits climax population densities in grassed areas about desert water holes and irrigated sections, and is common on *Distichlis* in such situations.

12. CHORTHIPPUS LONGICORNIS (Latreille) 1804 (*C. curtipennis* (Harris) 1841, *C. acutus* (Morse) 1903; also *Stenobothrus*)

ORMSBY COUNTY (near *Glenbrook* (Lake Tahoe) 16(VII)46, el. 7000 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 24(VI)40, el. 4500 ft. –LaR; *Verdi* 6(VIII)40, el. 4750 ft. –LaR).

As *Stenobothrus curtipennis*, Scudder (1880) recorded this species from "Lake Tahoe and Glen Brook, Nevada." In 1903, Morse described *S. acutus* from "Ormsby Co., Nev., July 6," (C. F. Baker) and wrote of it: "Closely allied to *curtipennis* . . . Possibly it is but a geographical race . . ." Baker's specimens came from the Carson Range west of Carson City at an approximate altitude of 5500 feet. I have specimens above and below this altitude in the near vicinity which can probably be regarded as topotypic. On such a basis, it is necessary to regard *C. acutus* as a synonym.

C. longicornis is usually found in high mountain meadows, and its 4500-foot occurrence in the vicinity of Reno is one of its low records—the extremely lush-meadow environment here may be the determinant factor. An Holarctic species.

13. PSOLOESSA DELICATULA DELICATULA (Scudder) 1876 (*Stirapleura*)

CLARK COUNTY (*Lee Cañon* (Spring or Charleston Mts.) 18-22(VIII)19, el. 4000 ft. –Rehn & Hebard); LINCOLN COUNTY (*Crestline* 4(IX)19, el. 6000 ft. –Rehn & Hebard); MINERAL COUNTY (*Walker* (*Wassuck*) *Range* 13/IX/19, el. 8000-8200 ft. –Rehn & Hebard) (Rehn 1942); WHITE PINE COUNTY (*Lehman Caves National Monument* 5–8/VI/37, 25/V/40, el. 7000 ft. –T. O. Thatcher). I have no specimens.

A common species of the "short grass plains" (Rehn 1942) and "short grasslands" (Ball et al. 1942), known to range, in Nevada, from altitudes of 4000 feet up to 8200 feet.

14. AGENEOTETTIX DEORUM (Scudder) 1876. (*A. scudderi* Bruner 1889, *A. occidentalis* Bruner 1905)

MINERAL COUNTY (3 mi. S. of *Lucky Boy Mine* (near Hawthorne) 5/IX/46, el. 5500 ft. –LaR & Gibson); PERSHING COUNTY (*Humboldt Queen Cañon* (Humboldt Range) 1/VIII/46, el. 4100 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 1/VIII/40, el. 4500 ft. –LaR).

This is a common Sagebrush Zone (*Artemisia tridentata*) species, having much the same habitus as the widespread *Melanoplus occidentalis*, with which it is usually associated. An important range and grassland species in Arizona (Ball et al. 1942), I have found it a species of shrubs rather than grasses where collected in Nevada, except in the vicinity of Reno, where the develop-

ment of extensive irrigated areas plus the natural occurrence of endemic marshlands have greatly added to the available food supply which in turn tends to decrease feeding selectivity; in the case of *A. deorum*, such selectivity is undoubtedly low initially.

15. AULOCARA ELLIOTTI (Thomas) 1870

LYON COUNTY (*Yerington* 23/VIII/46, el. 4400 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 1–4/VIII/40, el. 4500 ft. –LaR; *South Pyramid Lake dunes* 18/VI/46, el. 3850 ft. –LaR & Christensen).

A rather distinctive, weak flier closely resembling the associated *Melanopli* in many of its habits. At the Yerington locale, a large series of *A. elliotti* was taken by beating roadside grasses and weeds adjacent to a narrow, shallow pool into which both *Aulocara* and *Melanopli* flew and from which they were easily extracted. I am most familiar with *A. elliotti* in the Shadscale Zone in Nevada, with some overlap into the Sagebrush Zone, but it is recorded from the Creosote Zone as well in Arizona (Ball et al. 1942), where it is occasionally of great economic importance in short grass. From their numbers at Yerington, they were obviously making inroads on cultivated fields.

16. LIGUROTETTIX COQUILLETTI McNeil 1897

CLARK COUNTY (*Jean* 27/VI/32, el. 1800 ft. –M. J. Oösthuizen (Tinkham 1938); *Las Vegas* 10/VIII/07, el. 2028 ft. –Hebard); ESMERALDA COUNTY (*Miller's* 27/VIII/22, el. 4800 ft. –Rehn & Hebard); LYON COUNTY (*Fernley* 26/VIII/22, el. 4050 ft. –Hebard; *Mason* 6/IX/10, el. 4500-5700 ft. –Rehn & Hebard (Rehn 1924); 28/VIII/46, el. 5500 ft. –LaR); MINERAL COUNTY (*Mina* 3–4/IX/10, el. 4350–4850 ft. –Rehn & Hebard (Rehn 1924); *Thorne dune* 7/VII/41, el. 4600 ft. –LaR & Christensen); NYE COUNTY (*Beatty* 9–12/VIII/19, el. 3392 ft. –Rehn & Hebard) (Rehn 1924).

In 1909, Rehn and Hebard published records of their specimens taken during the 1907 collecting trip which included southern Nevada, making some significant observations: "A series of forty-nine specimens from localities in the Mohave and Las Vegas Deserts are referred to this species, to which *L. kunzei* Caudell from southern Arizona is closely related, differing only in the average larger size and slenderer caudal femora. The series is distributed as follows: . . . foothills Bird Spring Mountains, California and Nevada, August 11, 12 ♂♂, 9 ♀♀, 1 immature individual; Las Vegas, Nevada, August 10, 9 ♂♂, 2 ♀♀. . . . The Las Vegas and Kelso" (California) "series are uniformly paler and less contrastingly colored, the Las Vegas one very much paler and grayer, than the other lots; . . . at Las Vegas one small colony was located in a low thicket of spiny desert bushes. . . . True *coquilletti* appears to be a Mohavan and Nevadan form."

In his monograph, Rehn (1924) distributes *coquilletti* into three subspecies: *coquilletti* McNeil 1897, *cantator* Rehn 1924 and *kunzei* Caudell 1903, all three occurring in, or on, the border of Nevada. He assigns *cantator* to Miller's, Mina, Mason and Fernley; *kunzei* to the area just south of Nevada; while *coquilletti* occurs in adjacent southeastern California, all three intergrading in the area of southwestern Nevada–southeastern California. Mason is

the type locality of *cantator*. *L. coquilletti* is the most characteristic *Sonoran Trailway* orthopteran of which I have knowledge, all its recorded localities falling exactly within the confines of the Trailway.

A Creosote- and Shadscale-Zone shrub-inhabiting species, of no economic importance. Specimens which Rehn recorded from Las Vegas, Beatty, the Amargosa desert and other Nevada-California borderline localities all represent intergrades of *cantator* with the other two subspecies, *kunzei* and *coquilletti*, no typical individuals of either of these latter as yet known from the State.

Rehn's 1924 biologic notes on this form are worthy of repetition, being about the only such observations published:

"The scattered gray green bush of the Nevadan Basin, a land of broad desert plains and valleys and long mountain ranges, is the favored habitat of this subspecies. In the Great Basin greasewood (*Sarcobatus*), in *Atriplex*, and other species of the wiry and spiny shrubs which sparsely clothe the valleys and lower mountain slopes of this region, it will be found at home. In but two places (Daylight Spring and Hole-in-the-Rock Spring) was it found on Creosote bush (*Covillea*)" (*Larrea*) "which is so much favored by the other subspecies, which is readily understood when it is realized that this plant is almost absent from the area occupied by true *cantator*. Intermediates between *cantator* and the other subspecies frequently occur on creosote bush. This subspecies was noted by Hebard as stridulating after dark, the two specimens from Fernley, Nevada, being taken by stalking their sound well after night had fallen. Many others were stridulating at the same time in the brush of a *Sarcobatus* flat, and as long as the air remained warm and still they continued their performance. On the passing of a shower accompanied by a cool wind the entire assemblage ceased stridulating and nothing further was heard." Tinkham's (1938) record is that of specimens attracted to lights at night.

Subfamily OEDIPODINAE

THE GENERA OF OEDIPODINAE KNOWN (OR LIKELY) TO OCCUR IN NEVADA

1. Median pronotal carina entire or cut by one sulcus 2
—Carina cut by two sulci, or indistinct in middle portion 12
2. Hind wing nearly transparent; small 3
—Hind wings colored 4
3. Lateral pronotal carinae continuous; forewings marked irregularly ..... *Camnula*
—Carinae discontinuous; forewings regularly marked with three dark bands ..... *Encoptolophus*
4. Hindwing disc black, bordered with yellow ..... *Dissosteira*
—Hindwing disc not black 5
5 ♂ ♂ metasternal interspace rounded, longitudinally divided; ♀ ♀ metasternal interspace narrower than mesosternal interspace; body color generally dark; hindwing disc bright red to yellow ..... *Arphia*
—♂ ♂ metasternal interspace quadrate; ♀ ♀ metasternal interspace transverse; color generally lighter, usually mottled 6
6. Hindwing disc yellow 7
—Hindwing disc orange-red to orange 10
7. Hindtibiae red ..... (*Spharagemon*)
—Hindtibiae not red 8

8. Vertex rounded; robust ..... (*Hippiscus*)
—Vertex with a definite depression; slender 9
9. Median pronotal carina high; sulcus distinct ..... (*Lactista*)
—Carina low; sulcus shallow ..... (*Paltylactista*)
10. Median pronotal carina arcuate and toothed ..... (*Tropidolophus*)
—Carina cut by one sulcus 11
11. Brown; large ..... (*Tomonotus*)
—Green with black spots; small ..... (*Scirtetica*)
12. Hindwing black band usually present; median pronotal carina distinct; posterior pronotal margin (metazone) angulate 13
—Hindwing with no black band; carina obsolete in central portion of pronotum; posterior pronotal margin rounded or slightly angulate 26
13. Lateral pronotal carinae long and cut by the posterior sulcus; large, robust; anterior sulcus much shallower than posterior sulcus 14
—Lateral carinae indistinct or not cut by the posterior sulcus; small, slender; anterior and posterior sulci equal, or nearly so, in depth where bissecting the median carina 16
14. Hindwing disc blue or greenish-yellow; median pronotal carina indistinct ..... *Leprus*
—Hindwing disc yellow; carina distinct 15
15. Fore- and hindmargins of lateral pronotal lobes nearly parallel ..... *Xanthippus*
—Hindmargins slightly produced below ..... *Cratypedes*
16. Posterior angle of pronotal lateral lobes rounded; with or without a tooth 17
—Posterior angle acutely produced 24
17. Posterior angle of pronotal lateral lobes with a tooth 18
—Without a tooth 20
18. Hindwing disc rose-red; lateral elevations present adjacent to median carina of pronotum ..... *Trepidulus*
—Disc not red; lateral elevations not present 19
19. Median pronotal carina distinct and elevated on the metazone ..... *Conozoa*
—Carina weak and indistinct on metazone ..... (in part) *Trimerotropis*
20. Metazone rugose-tubercuate; lateral prominences present near median pronotal carina ..... *Derotmema*
—Pronotum smooth or only with scattered granules 21
21. Median pronotal carina bissected into two nearly equal portions by posterior sulcus; pronotal sides marked with black ..... (*Mestobregma*)
—Carina cut considerably before the middle by the posterior sulcus 22
22. Inner face of hindfemora bluish-black; antennae long; robust ..... *Hadrotettix*
—Inner face not bluish; antennae of normal length; slender 23
23. Hindwing anal veins strongly re-inforced; hindwing hind margin not evenly rounded ..... *Circotettix*
—Anal veins not re-inforced ..... (in part) *Trimerotropis*
24. Median pronotal carina weak and low; pronotum slightly saddle-shaped ..... (*Rehnita*)
—Carina strong and high 25
25. Inner face of hindfemora marked with blue; median pronotal carina high; large ..... *Metator*
—Inner face with no blue; carina moderately high; medium ..... *Trachyrhachis*
26. Posterior pronotal margin (metazone) rounded 27
—Margin angulate 29
27. Hindtibiae internal calcariae subequal to external calcariae; large, over ½ inch ..... *Anconia*
—Internal calcariae very long, about twice length of outer calcariae; small, less than ½ inch 28
28. Posterior angles of pronotal lateral lobes broadly rounded ..... *Xeracris*
—Angles produced ..... *Coniana*
29. Hindwing disc rose-red; forewings marked with dark base band ..... (*Heliastus*)
—Disc pale yellow; forewings marked with small dark spots ..... (*Cibolacris*)

17. ARPHIA PSEUDONIETANA (Thomas) 1870 (*A. tenebrosa* Scudder 1872, *A. sanguinaria* Stål 1873, *A. ovaticeps* Saussure 1888, *A. theresiae* (Brunner) 1895; also *Tomonotus*).

CHURCHILL COUNTY (*Fallon* 29/VIII/46, el. 4000 ft. –LaR); DOUGLAS COUNTY (*Genoa* 7/VIII/46, el. 4600 ft. –LaR & Trelease); LYON COUNTY (*Fort Churchill* 18/X/41, el. 4250 ft. –LaR & Trelease; *Wellington* 27/VIII/46, el. 4500 ft. LaR; *Yerington* 28/VIII/46, el. 4400 ft. – LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 25/V/40, 5/VIII/40, el. 4500 ft. –LaR; *Winnemucca Sink* 4/VII/41, el. 4500 ft. –LaR & Christensen).

A generally dark, often robust species possessing the reddest wings of the entire group in Nevada. Usually found about meadows in the vicinity of water. Also taken along the desert Carson river in the shade of ever-plentiful, wide-spreading cottonwoods (*Populus fremontii*). The most xeric occurrence of this characteristically water-requiring species was at a small spring on the eastern face of the desert Lake Range separating Winnemucca Sink from Pyramid Lake. The Sink, recently a lake some thirty miles long with a depth exceeding twenty feet in many places, is now an extensive alkali flat or playa devoid of life. The spring, situated a short distance up in the hills from the Sink, supplies a short stream only a few rods in length which supports a small but luxurious growth of cottonwoods and shrubbery, terminating in a tiny rush-rimmed pool, about which a few *A. pseudonietana* flourished. The nearest riverbottom breeding area of the type which this species seems so fond in Nevada is nearly twenty miles distant, where the Truckee river empties into nearby Pyramid Lake. Significantly, perhaps, these individuals were much lighter in color than the nearly black specimens found in meadows about Reno.

The 1946 Lyon County localities literally swarmed with the species, especially along roadside ditches. Thomas (1875) lists it from the "southeast border of Nevada" as *Tomonotus tenebrosus*. The species is undoubtedly a factor in the partial decimation of cultivated grasses locally, and is not particularly characteristic of any "Zone," having been recorded from the Creosote- to Sagebrush Zones—being associated with areas of open water, it is necessarily divorced to a degree from the surrounding environment. Henderson (1924) has recorded it as occasionally injurious in Utah.

18. ARPHIA BEHRENSI Saussure 1884.

Prof. Essig (1926) lists this species from "Nevada," but I have not been able to locate the original reference.

19. ENCOPTOLOPHUS PALLIDUS Bruner 1893.

Hebard (1935B) mentions this species for Nevada in a casual comment on its range: ". . . typical *pallidus* being confined to the areas of extreme aridity from the Panamint and Death Valleys of California and the Amargosa Desert of Nevada south to the Mexican border. . . ." I have no specimens. This seems to be a Creosote Zone form, and has been recorded as doing some range and crop damage in Arizona (Ball et al. 1942).

20. CAMNULA PELLUCIDA (Scudder) 1862 (*C. atrox* (Scudder) 1872).

DOUGLAS COUNTY (*Genoa* 6/VIII/46, el. 4600 ft. –LaR & Trelease); ELKO COUNTY (*Elko* 5/VI/39, el. 5000 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 30/V/40, 24/VI/40, el. 4500 ft. –LaR).

A very common species in the State, occurring up to over 7000 feet in the adjacent California High Sierras. Scudder (1880) recorded this species from "Reno and Glen Brook, Nevada" as *C. atrox* (Scudder) 1872. Bruner (1891) says "this is the insect which has occasionally been very destructive in parts of California and Nevada," and its depredations are occasionally of noticeable importance today. As I have found it in Nevada, it is characteristic of Sagebrush-Zone.

21. XANTHIPPUS CORALLIPES (Haldeman) 1852. (*X. pardalinus* (Saussure) 1861, *X. leprosus* Saussure 1884, *X. latefasciatus* (Scudder) 1892).

LANDER COUNTY (near *Hilltop* 1/VII/41, el. 6000 ft. –LaR & Christenson); WASHOE COUNTY (*Reno* (Truckee Meadows) 12/IV/40, 8/VI/40, 1/VII/40, el. 4500 ft. LaR); WHITE PINE COUNTY (*Ely* 29/V/40, el. 6470 ft. –LaR; *Lehman Caves National Monument* 27/V/37, 8/VI/37, 28/IV/40, 25/V/40, el. 7800 ft. –T. O. Thatcher). In addition, Hebard (1928), in describing *X. c. buckelli*, listed the locality "Pablo Creek, Toyabe Range, Nevada, 6400 feet, May 12, 1915, (E. G. Holt), 1 ♂, (wing disk orange), (Hebard Cln.)." I am not familiar with the locality, which is in central Nevada, and could be in any of the following counties: Eureka, Lander or Nye.

This is one of a group of Orthoptera common to Nevada which were originally described from material collected by the Stansbury expedition to the valley of the Great Salt Lake in 1850. Thomas (1875) listed it from "Nevada" as *Oedipoda corallipes*, and in 1892 Scudder wrote: "Mr. Bruner also sends me a specimen from Reno, Nevada, collected by Hillman," referring to *X. leprosus*. In the same publication, Scudder referred non-specifically to Nevada specimens of *X. pardalinus*, and also listed "Nevada (H. Edwards)" as part of the range of *X. affrictus*. In 1935, Hebard's studies led him to the conclusion that *affrictus* was a composite of two species and several forms. In a footnote he says: " We are able to give the following data on these. From the upper Missouri and Yellowstone Rivers and from Dakota = *corallipes latefasciatus*. From Nevada and Utah; these specimens cannot be located. From Rangeley, western Colorado and 'Colorado' = *corallipes leprosus*. From Yuma, Arizona = *affrictus* as here restricted." It is apparent that Scudder's *affrictus* Nevada records pertain instead to *corallipes*.

X. corallipes is a widespread species in the western United States, and one which exhibits considerable genetic diversity and a wide tolerance range, as evidenced by the number of apparent varieties which have been described. In Nevada, I am familiar with it only in the Sagebrush Zone. It has been listed as an economical range species in Arizona (Ball et al. 1942) and as an occasional pest of "the higher dry-farm grain" (Henderson 1924) in Utah, but it seems to be of little importance in Nevada.

22. XANTHIPPUS LATERITIUS Saussure 1884 (also *Hippiscus*).

LANDER COUNTY (near *Hilltop* 1-2/VII/41, el. 6000 ft. –LaR & Christensen);

WASHOE COUNTY (*Reno* (Truckee Meadows) 4/VI/40, el. 4500 ft. –LaR); WHITE PINE COUNTY (*Lehman Caves National Monument* 5/VI/37, el. 8000 ft. –T. O. Thatcher).

The common red-winged desert locust. On several occasions when I have found *X. lateritius* and *Trimerotropis suffusa* associated, the former seemed to occupy the higher portions of any particular sagebrush hill, while the latter was consistently found in the lower areas of the same hill; in such situations, *T. suffusa* generally outnumbered *X. lateritius*, which has not been noted in large numbers at any locality. *Lateritius* was originally described from Nevada, Saussure listing only "Amer. bor.; Nevada" for his specimens, which came from the Brunner collection. Strictly a Sagebrush Zone species in my experience.

23. XANTHIPPUS VITELLINUS Saussure 1884 (also *Hippiscus*).

Of this, Scudder (1892) said: "I have one female of this species from Nevada (H. Edwards), the locality from which it is described by Saussure. Mr. Bruner also sends me specimens from Reno, Nevada. . . ." I have no specimens. Saussure (1884) merely lists "Amer. bor. Nevada," from Brunner's collection.

24. XANTHIPPUS STIGMOSUS (Scudder) 1892 (also *Hippiscus*).

This species was described from California and southern Nevada specimens, the latter, at least, taken by G. R. Crotch. I have no specimens.

25. XANTHIPPUS CALTHULUS Saussure 1884 (also *Hippiscus*).

In 1892, Scudder wrote: "I have a single female of this species taken by Crotch in southern Nevada. Saussure's specimens also came from Nevada, but Bruner sends me a specimen from Placer County, California, taken in June." I have no specimens. Saussure (1884) listed only "Nevada" in his description from Brunner's specimens.

26. CRATYPEDES NEGLECTUS (Thomas) 1870 (also *Hippiscus*, *Arphia* and *Xanthippus*).

ELKO COUNTY (*Elko* 30/VI/41, el. 5000 ft. –LaR & Christensen); LANDER COUNTY (near *Hilltop* 1–2/VII/41, el. 6000 ft. –LaR & Christensen); WASHOE COUNTY (*Cottonwood Cañon* (Peavine Mt., Near Reno) 22/VI/46, el. 5500 ft. –LaR & Christensen).

A large, yellow-winged species of weaker flight than its associated *Trimerotropis*, and common in the northern half of Nevada. As *Oedipoda neglecta*, Thomas (1875) wrote that "it extends into the borders of Nevada. . . ." At the Peavine Mountain locality, the species was common to open, south slopes surrounded by the dominant conifer, *Pinus ponderosa jeffreyi*, a habitat it shared with the less common *Trimerotropis caeruleipennis*. A strong wind was sweeping the slope, making collecting difficult, since flushed specimens were carried some distance before settling; however, those swept into the shade under the pines were quick to fly into the sun again.

Henderson (1924) listed the species as "found occasionally in the higher dry-farm grain fields" of Utah, where it may presumably be of occasional economic significance. It has never been found important in Nevada.

When discussing the species in 1892, Scudder wrote it occurs "westward to various localities in Nevada (H. Edwards, Camp Hallock" (Halleck), "Nev. (E. Palmer), Ruby Valley, Nev. (R. Ridgway), near Lake Tahoe, California (S. Henshaw, in Capt. Wheeler's explorations of 1876." Saussure's 1884 mention is merely that of "Amer. boreal.; Nevada," from some of Brunner's material.

27. LEPRUS WHEELERI (Thomas) 1875.

Scudder (1900A) reported specimens from "Humboldt Station, Nevada, July 29." I have no specimens. Henderson (1924) was unable to demonstrate any specimens of this species in the material he had from Utah, and there are still some uncertainties regarding it.

28. LEPRUS INTERIOP Bruner 1905.

WHITE PINE COUNTY (*Lehman Caves National Monument* 18/VII/37, 30/IX/39, el. 8000 ft. –T. O. Thatcher). I have no specimens.

Rehn and Hebard (1909) wrote of this species: "A single male of this species from the foothills of the Bird Spring Mountains, McCullough Range, Nevada, August 11, has been examined. It is very similar in character to a series from the Salt Lake Valley, Utah, and was collected on a bare volcanic mountain side. The specimen is slightly smaller than the original measurements of the male sex given by Bruner. This is the first record of this species from Nevada, and in fact from any locality but the Salt Lake Valley." As a biologic note, Rehn and Hebard wrote in 1906: "This series was only taken after long and careful search." (near Salt Lake City, Utah). "There was but one place on the steepest portion of Ensign Peak where the insect could be found, and although the females were easily captured when found, the males flew vigorously. So steep was the hillside that it was bare of everything but scattered grasses and an occasional sage-brush When at rest the insects were wonderfully protected by their coloration."

29. LEPRUS GLAUCIPENNIS Scudder 1900.

Casually mentioned for Nevada by Hebard (1935B): "Material from southeastern California and southern Nevada appears to be atypical of this insect." I have no specimens.

30. DISSOSTEIRA CAROLINA (Linné) 1758.

DOUGLAS COUNTY (*Genoa* 7/VIII/46, el. 4600 ft. –LaR & Trelease); LINCOLN COUNTY (*Hiko* 13/VII/40, el. 3800 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 11/VI/39, el. 4500 ft. –LaR); WHITE PINE COUNTY (*Lehman Caves National Monument* 18/VIII/39, el. 7000 ft. –T. O. Thatcher; *Shoshone* 11/IX/46, el. 4500 ft. –G. C. Christensen).

This large, conspicuous species seems more at home on the wing than any other Nevada grasshopper; the resemblance to butterfly flight is remarkable in some individuals. The animal is an habitué of grassed, semi-marshy bottomlands and fields, and generally shares such a habitat with the equally-conspicuous *Arphia pseudonietana*. Thomas (1873B) listed it from Nevada as *Oedipoda carolina*. At times it is quite abundant. Henderson (1924) said that "I have never been in a field in Utah or Idaho in the proper season of the year without finding it. It is no doubt outnumbered in our state" (Utah) "by a few other species, but being so large its ravages are at times very severe." Henderson also qualifies the common statement that *D. carolina* is found on roadways by saying: "This is true of adults only. The nymphs are found in the vegetation of fields, pastures, and grazing lands where they ravenously devour excessive amounts of forage."

31. DISSOSTEIRA SPURCATA Saussure 1884.

Listed for Nevada by Prof. Essig (1926) but I cannot locate the original reference. It is common in California.

32. DEROTMEMA DELICATULUM Scudder 1900.

Rehn and Hebard (1909) wrote: "A series of fifty-four Californian and Nevadan specimens is now before us, the following localities being represented: . . .; foothills Bird Spring Mountains, Nevada, August 11, ten males, eight females; Arden, Lincoln" (now Clark) "County, Nevada, August 9, one female. When compared with two pairs from Sentinel, Maricopa County, Arizona, the eyes of all the Californian and Nevadan individuals are seen to be slightly less prominent than in the Sentinel specimens, but in all the essential characters they fully agree." Also "The Arden specimen is much like Kelso individuals, but the head and portions of the pronotum and cephalic and median limbs are suffused with dull vermillion."

D. delicatulum seems confined to the Creosote Zone. I have no specimens.

33. DEROTMEMA HAYDENI RILEYANUM Saussure 1884.

Scudder (1900C) said of this: "I have specimens from Humboldt Station, Nevada." Saussure described *rileyanum* from "Amer. borealis; Salm. County, Idaho (Prof. Riley)." I have no specimens. Apparently predominantly a Shadscale Zone species.

34. TREPIDULUS ROSACEUS (Scudder) 1889 (*T. penelope* (Caudell) 1901; *Araeopteryx*, also *Mestobregma*).

According to Rehn and Hebard (1909): "At Las Vegas, Nevada, August 10" (1907) "this species was found numerous in bare desert places, both the typical phase with the wing roseate proximad and one with the same portion hyaline with an extremely faint whitish suffusion being taken. The series numbers twenty-five males and seven females, each phase represented by sixteen

individuals. Fourteen males and two females have the wings roseate and eleven males and five females have the same members hyaline.

"There is little variation in size, although the tegmina and wings vary somewhat in length. The degree of production of the ventro-caudal angle of the lateral lobes of the pronotum varies considerably and in a number of specimens the angle is well rounded. The character of this angle cannot be correlated with the color of the wings. The general color is more ashy in some individuals than in others, sometimes touched with dull reddish and again with the maculations more decided than in others. The Nevada specimens as a rule are paler than representatives from southeastern Arizona, but they are well matched in individuals from the lower Arizona desert at Yuma and Florence."

Another Creosote Zone species. I have no specimens.

(MESTOBREGMA PLATTEI RUBRIPENNE (Bruner) 1905. (also *Trachyrhachis*).

Listed as *M. rubripenne* by Rehn and Hebard (1909) as "a single female . . . secured in the foothills of the Bird Spring Mountains, California, August 11, in sand." This locality is practically at the Nevada-California line, and the species is undoubtedly to be found in Nevada).

35. METATOR NEVADENSIS (Bruner) 1905. (also *Trachyrhachis*).

LYON COUNTY (*Yerington* 28/VIII/46, el. 4400 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 2/VI/40, el. 4500 ft. –LaR).

This distinctively-marked, red-winged species is associated with the similarly red-winged *Arphia pseudonietana* in well-watered meadow bottoms, but unlike the latter seldom calls attention to its presence by flying when disturbed; the instinct of *nevadensis* is to drop quietly to the ground and lose itself in dense vegetation. Because of such habits, it is easily overlooked in a locality well-populated with *A. pseudonietana*, whose flashy and noisy flight tends to cloak the presence of *M. nevadensis*. Hebard (1928) wrote that "In Nevada and northwestward" *Metator pardalinus* "is supplanted by *M. nevadensis* (Bruner)." In my experience, a Shadscale species probably with some overlap into Sagebrush Zone.

36. CONOZOA WALLULA (Scudder) 1880 (*C. behrensi* Saussure 1884; *Psinidia*).

CHURCHILL COUNTY (*Allen Spring* (22 mi. S. of Fallon) 25/VIII/46, el. 4800 ft. –LaR; *Fallon* 29/VIII/46, el. 4000 ft. –LaR); DOUGLAS COUNTY (*Genoa* 6/VIII/46, el. 4600 ft. –LaR & Trelease); LYON COUNTY (*Yerington* 28/VIII/46, el. 4400 ft. –LaR); WASHOE COUNTY (*Pyramid Lake* 17–24/VIII/41, el. 3850 ft. –LaR & Trelease; *Reno* (Truckee Meadows) 13–15/V/40, 5/VIII/41, el. 4500 ft. –LaR; *Washoe Lake* 10/VII/41, el. 4500 ft. –LaR & Christensen; *Winnemucca Sink* 4/VII/41, el. 4500 ft. –LaR & Christensen).

A very common, moderate-sized yellow-winged desert flier. Scudder described the species as *Psinidia wallula* and as one of the localities listed "Reno, Nev., August 18." He knew it from practically the entire Pacific coast. When found in the vicinity of meadowlands, *C. wallula* is characteristic

of dry, dusty roads (as an imago), where it is often associated with *Dissosteira carolina*. From my records, predominantly an *Atriplex* zone species, and perhaps of occasional economic importance.

37. CONOZOA SULFICRONS (Scudder) 1876.

CLARK COUNTY (*Las Vegas* 31(VII)30, el. 2250 ft. –E. R. Tinkham); LINCOLN COUNTY (*Hiko* 12(VIII)40, el. 3800 ft. –LaR).

Rehn and Hebard (1909) listed the first Nevada specimens: "At Las Vegas, Nevada, a series of ten males and ten females of this species was taken on August 10" (1907) . . . "No Nevada records have previously been published." Tinkham's record is that of specimens coming to light at night.

38. TRIMEROTROPIS CRISTATA McNeill 1900.

Rehn and Hebard (1909):

"Two males and two females of this very pale colored species were taken, August 10, at Las Vegas, Nevada, in typical desert surroundings.

"The specimens are quite uniform in coloration and size.

"The previous records of the species are from San Julio, Lower California, and Salt Lake Valley, Utah." I have no specimens.

39. TRIMEROTROPIS REBELLIS (Saussure) 1888. (also *Conozoa*).

CHURCHILL COUNTY (*Rawhide Sands* 28/VIII/46, el. 4200 ft. –LaR); HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 31/VII/46, el. 4800 ft. LaR); WASHOE COUNTY (*South Pyramid Lake dunes* 18/VI/46, el. 3850 ft. –LaR & Christensen; *Truckee Meadows* (Reno) 2/VIII/41, el. 4500 ft. –LaR).

A distinctive, readily-recognizable desert species very common in waste areas; an habitué of the *Atriplex* zone with some overlap into *Artemisia*.

40. TRIMEROTROPIS BILOBATA Rehn & Hebard 1906.

I have no definite records of this species for Nevada, but Hebard (1929) wrote: "We believe that it is very widely distributed over the Great Basin, in desert environment at lower elevations."

41. TRIMEROTROPIS CAERULEIPENNIS Bruner 1885 (also *Pseudotrimerotropis*).

LYON COUNTY (near *Mason* 28/VIII/46, el. 5600 ft. –LaR); MINERAL COUNTY (*Hawthorne* 27/VIII/46, el. 4400 ft. –LaR; *Whiskey Flat* (15 mil. S of Hawthorne) 5/IX/46, el. 5000 ft. –LaR & Gibson); PERSHING COUNTY (*Humboldt Queen Cañon* (Humboldt Range) 1/VIII/46, el. 4100 ft. –LaR); STOREY COUNTY (*Virginia City* 21/VIII/46, el. 6500 ft. –LaR); WASHOE COUNTY (*Peavine Mt.* (Reno) 18/VIII/39, 11/VI/40, el. 5000 ft. –LaR; *Steamboat Springs* (Truckee Meadows) 22/VII/46, el. 4600 ft. –LaR).

A widespread and often common species, especially at the higher altitudes; seemingly restricted to the *Artemisia* zone with some overlap into *Atriplex*. Somewhat wary, and often quite noisy in flight. Tinkham (1938) lists the species as coming to night lights in the "Nevada desert, 15 miles north of

Coleville, Calif., several specimens," taken 8/VIII/30, presumably by Tinkham. In 1909, Rehn and Hebard specified the blanket range of "Washington to Montana and Wyoming, south to southern California and Arizona."

42. TRIMEROTROPIS CYANEIPENNIS Bruner 1889 (*T. cyanea* Scudder 1902; also *Pseudotrimerotropis*).

MINERAL COUNTY (vicinity of *Lucky Boy Mine* (Walker Range) 5/IX/46, el. 5500 ft. –LaR & Gibson).

Rehn and Hebard (1909) listed specimens from the Providence Mountains, San Bernardino County, California, close to the Nevada line.

43. TRIMEROTROPIS SPARSA (Thomas) 1875 (*T. azurescens* Bruner 1889, *T. perplexa* Bruner 1889; also *Pseudotrimerotropis*).

Hebard (1928) makes the statement: "The species is, however, present extensively in Nevada and there may be found to be racially separable." I have no specimens.

(TRIMEROTROPIS PSEUDOFASCIATA Scudder 1876.

Rehn and Hebard (1909) give a blanket range of "Washington to southern California, east to Colorado" for the species, which is undoubtedly found in Nevada).

44. TRIMETOTROPIS STRENUA McNeill 1901 (*T. montana* McNeill 1901; also *Pseudotrimerotropis*).

CHURCHILL COUNTY (*Rawhide Sands* 25–28/VIII/46, el. 4200 ft. –LaR; *Sand Spring dune* 30/VII/46, el. 4500 ft. –LaR); HUMBOLDT COUNTY (*Paradise Valley dunes* 31/VII/46, el. 4800 ft. –LaR); LYON COUNTY (near *Mason* 28/VIII/46, el. 5500 ft. –LaR); MINERAL COUNTY (*Hawthorne* 27/VIII/46, el. 4400 ft. –LaR; *Walker Lake* 26–27/VIII/46, el. 4200 ft. –LaR).

At the Paradise Valley locality, the species was commonly found feeding and resting in the numerous clumps of sand grass, *Oryzopsis hymenoides*. In areas where dried, almost blood-red leaves of an unidentified plant lay scattered about after the death of the plant, a nearly blood-red color phase of *T. strenua* predominated, achieving considerable protection from the color resemblance—without such leaves for background, red insects would have been flagrantly conspicuous against the white dune sand. The reddish coloration was in the nature of a deep suffusion over the basic pattern of light-and-dark banding without eliminating the pattern. This weed did not occur at Sand Spring, and no red individuals were seen there. Rehn and Hebard (1906), in a discussion of the distribution of *T. vinculata* (a synonym of *T. pallidipennis*) in Colorado, mentions the presence of a brick-red color phase prevalent in a region (Garden of the Gods) where the predominant ground color is the same tint. In 1909, Rehn and Hebard wrote: "This Great Basin and interior desert form is represented by four males . . . one" (from) . . . "the foothills of the Bird Spring Mountains, Lincoln" (now Clark) "County, Nevada, August 11." In

1929, Hebard again mentioned its interior range: "The insect is widely distributed over the Great Basin region. . . ."

T. strenua is very close to *T. californica* Bruner 1890, and may eventually prove to be a variety of the latter.

45. TRIMEROTROPIS ALBESCENS McNeill 1901 (also *Pseudotrimerotropis*).

CHURCHILL COUNTY (*Sand Spring dune* 5/VII/41, el. 4500 ft. –LaR & Christensen; 30/VII/46, LaR); DOUGLAS COUNTY (*Lake Tahoe* 27/VI/40, el. 6300 ft. –LaR); MINERAL COUNTY (*Lucky Boy Mine* (Hawthorne) 5/IX/46, el. 5500 ft. –LaR & Gibson; *Whiskey Flat* (15 mi. S of Hawthorne) 5/IX/46, el. 5000 ft. –LaR & Gibson); WASHOE COUNTY (*Washoe Lake* 10/VII/41, el. 4500 ft. LaR & Christensen).

A light-colored, effortless and wary flier found about sandy and sand-colored soils, ranging from hot salt flats to pine timber, but nowhere common. At the Whiskey Flat locality, *T. albescens* was sparsely interspersed in a large population of *Circotettix carlinianus* and *Trimerotropis caeruleipennis*, and was the only yellow-winged species present. Seemingly a species characteristic of the *Atriplex* zone, and one of the smallest of Nevada *Trimerotropis*.

46. TRIMEROTROPIS LATIFASCIATA Scudder 1881 (*T. snowi* Rehn 1905; also *Pseudotrimerotropis*).

DOUGLAS COUNTY (*Genoa* 6/VIII/46, el. 4600 ft. –LaR & Trelease).

Rehn and Hebard (1909) have: "A single female of this species was taken at Las Vegas, August 10" (1907). "While somewhat larger than Scudder's measurements, this individual agrees very well with his description." In discussing the synonymy of *T. snowi*, Hebard (1935B) makes further mention of its Great Basin distribution in the casual remark: "It" (*T. snowi*) "agrees very closely with material of *latifasciata* before us from Utah and Nevada." One of the two Nevada species immediately recognized by the abnormally wide hind wing fuscous band. Known to range from the *Larrea* to the *Artemisia* zones.

47. TRIMEROTROPIS LATICINCTA Saussure 1884 (also *Pseudotrimerotropis*).

CHURCHILL COUNTY (*Rawhide Sands* 25–28/VIII/46, el. 4200 ft. –LaR); DOUGLAS COUNTY (*Genoa* 6/VIII/46, el. 4600 ft. –LaR & Trelease); LYON COUNTY (*Wellington* 27/VIII/46, el. 4500 ft. –LaR; *Yerington* 28/VIII/46, el. 4400 ft. –LaR); WHITE PINE COUNTY (*Shoshone* 11/IX/46, el. 4500 ft. –G. C. Christensen).

A somewhat wary species, with strong powers of flight. *T. laticincta* and *T. latifasciata* are the only Nevada species possessing a black wing band wider than the yellow-colored disc. Predominantly an *Atriplex* zone species.

48. TRIMEROTROPIS FONTANA (Thomas) 1876 (*T. juliana* Scudder 1876, *T. caeruleipes* Scudder 1880, *T. caliginosa* McNeill 1900, *T. tesssellata* McNeill 1901, *T. ferruginea* McNeill 1901; also *Pseudotrimerotropis*).

CHURCHILL COUNTY (*Sand Spring* 5/VII/41, el. 4500 ft. –LaR & Christensen); WASHOE COUNTY (*Pyramid Lake* 17/VIII/41, el. 3900 ft. –LaR & Trelease; *Truckee Meadows* (Reno) 21/V/40, 10/VI/40, el. 4500 ft. –LaR; *Winnemucca Sink* 4/VII/41, el. 4500 ft. –LaR & Christensen); WHITE PINE COUNTY (*Lehman Caves National Monument* 28/IX/39, el. 7000 ft. –T. O. Thatcher).

A common and widespread medium-sized desert locust. *T. caeruleipes* was recorded by Rehn and Hebard (1909) as: "A single male from Ormsby County, Nevada (Baker)," . . . (has) . . . "also been examined." In 1935B, Hebard wrote: "We are satisfied that *Trimerotropis tessellata* McNeill, described from Turkey Tanks" (Arizona) "in 1901, is a synonym. That name was placed in the synonymy of *Trimerotropis caeruleipes* Scudder by Caudell in 1902, which was in turn placed as a synonym of *Trimerotropis fontana* (Thomas) by Hebard in 1928. The relationship between *cincta* and *fontana* is very close."

Thomas described *fontana* from three specimens collected by J. D. Putnam at Spring Lake, Utah, and expressed doubt as to its distinctness from Scudder's *citrina*.

(TRIMEROTROPIS INCONSPICUA Bruner 1904.

I have no records for this, but Hebard (1929) says: "We have reason to believe that it has a wide distribution in the Great Basin.").

49. TRIMEROTROPIS PALLIDIPENNIS (Burmeister) 1839 (*T. vinculata* Scudder 1876, *T. similis* Scudder 1880; also *Pseudotrimerotropis*).

CHURCHILL COUNTY (*Sand Spring dune* 30/VII/46, el. 4500 ft. –LaR); EUREKA COUNTY (*Eureka* 9/IX/46, el. 6840 ft. G. C. Christensen); HUMBOLDT COUNTY (*Paradise-National Summit* (Santa Rosa Mts.) 22/VI/41, el. 7600 ft. –LaR & Christensen); LANDER COUNTY (near *Hilltop* 2/VII/41, el. 6000 ft. –LaR & Christensen); LINCOLN COUNTY (*Alamo* 13/V/40, el. 2800 ft. –LaR); PERSHING COUNTY (*Nightingale Mts.* (west side) 22/VII/46, el. 4100 ft. –LaR); WASHOE COUNTY (*Pyramid Lake* 18–20/VI/46, el. 3900 ft. –LaR & Christensen; *Truckee Meadows* (Reno) 24/VI/40, el. 4500 ft. –LaR; WHITE PINE COUNTY (*Ely* 29/V/40, el. 6470 ft. –LaR; 11/IX/46, –G. C. Christensen; *Lehman Caves National Monument* 28/VIII/39, 18/IX/39, 14/IX/40, el. 7000 ft. –T. O. Thatcher; *Shoshone* 11/IX/46, el. 4500 ft. –G. C. Christensen).

A large, flashy, yellow-winged species, probably the strongest of the desert fliers of this group in Nevada. Its flights are often of long duration, and individuals commonly ascend until well out of sight; I once checked a specimen which gyrated about a sagebrush slope for 17 minutes in one flight before finally coming to rest. Had he utilized that energy in straight flight, he would not now be a cabinet specimen. As *T. vinculata*, Rehn and Hebard (1909) discussed its Nevada distribution:

"This widely distributed species is represented by a considerable series of specimens distributed as follows: . . .; foothills Bird Spring Mountains, Nevada, August 11, one female; Arden, Lincoln" (now Clark) "County, Nevada, August 9, one male; Las Vegas, Nevada, August 10, four males.

"As a rule the Catalina, Miramar and Pasadena" (California) "individuals are duller than specimens from the San Bernardino Mountains, Cima, Indio, Providence" (California) "and Bird Spring Mountains of Las Vegas" (Neva-

da). "The single Arden specimen has the cephalic portion of the body and limbs well sprinkled and partially washed with pinkish-red."

Tinkham (1938) gives *pallidipennis* as coming to night lights "West of Jean on the California-Nevada line," 10 specimens, 37(VI)32, M. J. Oösthuizen.

50. TRIMEROTROPIS SUFFUSA FALLAX Saussure 1884 (also *Circotettix*).

EUREKA COUNTY (*Eureka* 9/IX/46, el. 6840 ft. –G. C. Christensen); LANDER COUNTY (near *Hilltop* 2/VII/41, el. 6000 ft. –LaR & Christensen); WASHOE COUNTY (*Truckee Meadows* (Reno) 21/V/40, el. 4500 ft. –LaR).

This widespread species also occurs commonly in the adjacent California High Sierras up to elevations exceeding 7000 ft. It is a strong, wary flier, often rising to great heights above the ground in wild gyrations. Hebard (1929) felt that "Saussure's *fallax* and McNeill's *conspersa* and *variegata* are based on western material of this species, representing at best not more than a geographic race." In the same publication, Hebard records *T. suffusa* from as high as 8500 feet in the Colorado Rockies. Scudder (1900B) reported *Circotettix suffusa* (Scudder) 1876 from the vicinity of "Lake Tahoe, Nev., Sept., Oct. (Henshaw—Wheeler's expl.)." The species here in Nevada seems to predominate in the *Artemisia* zone with considerable overlap into the *Pinus* zones above.

(TRIMEROTROPIS ARIZONENSIS Tinkham 1947.

A species described by Tinkham from "the barren Black Mountains in the extreme northwestern corner of Arizona within two to three miles of the Colorado River" (Tinkham 1947), and which he regards as "a representative species of the Nevada Desert, a subtype of the Sonoran Desert, which is found in the northwestern corner of Arizona, southwestern corner of Utah, southern Nevada and adjacent areas of California including Death Valley." As such, critical search may reveal it in southern Nevada).

51. HADROTETTIX TRIFASCIATUS (Say) 1825 (*H. hoffmanni* (Thomas) 1875; also *OEdipoda*).

This species was recorded by Thomas (1875) from "southeastern Nevada," as *OEdipoda trifasciata* and the synonym *OE. hoffmanni*. *OE. hoffmanni* is listed by Thomas at the end of the discussion of Acrididae as from "Nevada," although in the description of the species, he says it is named "in honor of Dr. W. I. Hoffman, who collected it while accompanying the expedition in Arizona." I have no specimens.

52. CIRCOTETTIX UNDULATUS (Thomas) 1872 (*C. lobatus* Saussure 1888).

WHITE PINE COUNTY (*Lehman Caves National Monument* 3/VII/39, 14/IX/39, el. 7000 ft. –T. O. Thatcher).

Rehn (1921) mentions an *undulatus* from Nevada, incorrectly referred to *C. thalassinus* by Scudder. Thomas (1873B) listed Nevada for the species,

and Saussure (1884) had: "America borealis; Colorado; Nevada." I have no specimens.

53. CIRCOTETTIX CARLINIANUS STREPITUS (Rehn) 1921 (*Aerochoreutes*).

ELKO COUNTY (*Carlin* 17/IX/19, el. 4900 ft. –Rehn & Hebard; *Montello* 19/IX/19, el. 5000 ft. –Rehn & Hebard; *Wells* 18/IX/19, el. 5650 ft. –Rehn & Hebard); HUMBOLDT COUNTY (*Prince Royal Canyon* (Star Peak Range) 16/IX/19, el. 4500–5000 ft. –Rehn & Hebard) (Rehn 1921); LANDER COUNTY (*Buffalo Valley* 26(VI)41, el. 4500 ft. –Trelease); MINERAL COUNTY (*Whiskey Flat* (15 mi. S of Hawthorne) 5/IX/46, el. 5000 ft. –LaR & Gibson).

Collected by Packard in "Reno, Nevada, August 18, 1887" (Scudder 1880). Saussure (1884), like Scudder, used the spelling "*carlingianus*." Named for Colonel Carlin, of early Government western geographical surveys. Rehn (1921) described *strepitus* from a "♂; Prince Royal Canyon, Star Peak Range," etc. Portions of his discussion which are pertinent are: "It is possible that *strepitus* is a more recent type than *car. carlinianus*, as its present area of distribution in large part was occupied in recent geologic times by Lakes Bonneville and Lahontan. It is equally possible that originally it was driven into the Basin ranges by these bodies of water, and that by the process of survival individuals with longer wings, and probably better power of flight, formed the beginnings of this race, which may have repopulated the flat lands and valleys when the lakes subsided through evaporation."

Hebard (1929) again mentions its Nevada occurrence, and in 1930, wrote of it as "the most powerful flier of North American grasshoppers." In my experience in Nevada, there are several species of considerably more powerful flight, i.e., *Dissosteira carolina* and *Trimerotropis pallidipennis*, but certainly none which make more noise in flight. At the Whiskey Flat locality, where the dominant population was *strepitus*, the species was conspicuous among other oedipodines by virtue of its much greater size, heavier build and, at times, deafening clatter on the wing. It is still a common misconception that this oedipodine "stridulation" is accomplished by an interaction of tegmen and hind wing—however, Karny (1908), in Europe, proved that such sound is produced by a manner of opening and closing the fan-like hind wing. Isely (1936) called particular attention to this fact and corroborated it with additional simple experiments, as well as citing the supplementary evidence of his contemporaries. I have found, by removing the tegmina of *Circotettix carlinianus strepitus*, that "stridulation" was still possible, although on a somewhat reduced scale, probably because such removal resulted in a general impairment of flight.

54. CIRCOTETTIX VERRUCULATUS (Kirby) 1837.

WHITE PINE COUNTY (*Lehman Caves National Monument* 8/VII/39, 7800 ft., 6/XI/39, el. 7000 ft. –T. O. Thatcher). I have no specimens.

55. CIRCOTETTIX MACULATUS Scudder 1881.

Scudder (1900B) listed this species from the "mountains near Lake Tahoe, Nev., Oct. (H. W. Henshaw—Wheeler's Expl.)" and "Nevada, July (O.

S. Westcott)." Saussure (1884) listed "California; Nevada." I have no specimens.

56. CIRCOTETTIX THALASSINUS Saussure 1884.

Saussure (1884) described the species from "Nevada" in the Brunner collection. According to Rehn (1921) Scudder's 1900B record for the state ("Nevada (H. Edwards)") is in error, and should be referred to *C. undulatus*, which see. I have no specimens.

57. CIRCOTETTIX CROTALUM Rehn 1921.

CLARK COUNTY (*Spring Mountains* (Charleston Peak) 19(VIII)19, el. 10,200 ft. -Hebard; (Lee Cañon) 18-20(VIII)19, els. 7000-8500 ft. -R & H) (Rehn 1921).

Known only from the type locality, *C. crotalum* was taken in considerable numbers by Rehn and Hebard. Rehn (1921) made the following observations on the species: "moderately numerous on bare surfaces of pebbles and limestone fragments in open forest" (Lee Cañon); "scarce on rocky and very steep slopes" (Charleston Peak); "This series shows . . . that the species varies individually very greatly in size, even at the same elevation in Lee Canyon; also that the form of fastigium varies considerably in shape and in the relative proportions of the same, although this area is, when the series is considered as a whole, of a distinctly narrower type than in *coconino*. The basic coloration is variable . . . but there appears to be some environmental correlation here." I do not have it.

58. ANCONIA INTEGRA Scudder 1876.

CLARK COUNTY (*Las Vegas* 10(VIII)07, el. 2250 ft. -R & H) (Rehn and Hebard 1909); NYE COUNTY (Beatty 6(I)40, el. 3300 ft. -LaR).

A rather small, agile flier. Rehn and Hebard (1909) listed the following pertinent remarks: "This desert-loving species was taken at . . .; Las Vegas, Nevada, August 10, seven males, one female, one immature individual; . . . The series exhibits a considerable amount of individual variation in size, at least in the male sex, while the color variations are extensive as usual in the species. Specimens with green or very pale greenish in their coloration comprise half (Las Vegas) or slightly less than half (Indio)" (California) "of the larger lots, while the greenish individuals from both of the localities are more maculate than is the case with greenish individuals from Arizona. The Indio and Cottonwood" (California) "individuals are as a rule more uniformly maculate than the Las Vegas specimens.

"The range of the species is now known to extend from Las Vegas, Nevada, and Death Valley, California, to Indio and Yuma, and from the western portion of the Mohave Desert to at least the vicinity of Tucson."

59. ANCONIA CAERULEIPENNIS Bruner 1906.

Described by Bruner from "Nevada," with the type locality designated as Hawthorne (Mineral County). Strohecker (1946) communicates the fol-

lowing specific record: *Hawthorne* 2(V)43, el. 4100 ft. –H. S. Wallace. I have not taken it.

Rehn and Hebard (1909A) wrote: "This most interesting insect, which was described from a single female from Hawthorne, Nevada, is represented by two males and seven females from the vicinity of El Paso" (Texas). "One of the most striking features of this species is the subinflated disk of the prozona and metazona, while the principal sulcus is deeply impressed and the median carina elevated or subtectate on the cephalic portion of the prozona. The ease with which this species in life loses its caudal limbs is remarkable."

60. CONIANA SNOWI Caudell 1915.

CHURCHILL COUNTY (*Rawhide Sands* 25–26(VIII)46, el. 4200 ft. –LaR; *Sand Spring dune* 5(VII)41, el. 4500 ft. –LaR & Christensen; 30(VII) 46. –LaR)

This small, spotted species I have only from the vicinity of sanded areas, where it is sometimes quite common. Apparently restricted to Shadscale Zone.

61. XERACRIS PARVICEPS (Walker) 1870 (*Thrincus? aridus* Bruner 1889; *Cibolacris, Heliastus*).

CLARK COUNTY (*Bunkerville* 7(IX)26, el. 1200 ft. –Hebard; *Lee Cañon* (Spring Mountains) 18–22(VIII)19, el. 4000 ft. –R & H; *St. Thomas* 8(IX)26, el. 1250 ft. –Rehn); LINCOLN COUNTY (*Alamo* 15(V)40, el. 3750 ft. –LaR); LYON COUNTY (*Mason* 6(IX)10, el. 5000 ft. –R & H); MINERAL COUNTY (*Hawthorne* 12–13(IX)19, el. 4300 ft. –R & H; *Mina* 3(IX)10, el. 4800 ft. –R & H; *Walker Lake* (south end) 13(IX)19, el. 4100 ft. –R & H); NYE COUNTY (*Beatty* 9–12(VIII)19, el. 3392 ft. –R & H; *Miller's* 27(VIII)22, el. 4900 ft. –Hebard) (Hebard 1937); WASHOE COUNTY (*Pyramid Lake dunes* 1(IX)41, el. 3850 ft. –LaR & Trelease).

A distinctive species which has been taken over most of the State. In 1909, Rehn wrote: "The series examined in this connection embraces the following localities: . . . foothills Bird Spring Mountains, Nevada, three males, one female."

62. XERACRIS MINIMUS (Scudder) 1909 (*Cibolacris, Heliastus*).

Rehn and Hebard (1909) wrote of this species: "This little known species is represented by material from near the foothills of the Bird Spring Mountains, both in California and Nevada, a series of seventeen males, eight females and one immature specimen being taken on August 11" (1907). "Three individuals of each sex were also taken the same day in Nevada, immediately over the line from Lyons, California."

"The species is only known from Palm Springs, Colorado Desert, California, Bill Williams Fork, Arizona, and foothills of the Bird Spring Mountains, near the California-Nevada boundary." I have no specimens.

Subfamily BATRACHOTETRIGINAE

63. BRACHYSTOLA MAGNA (Girard) 1854 (*Brachypeplus*).

Thomas (1875) listed the species from "southeast Nevada and northern Arizona" as *Brachypeplus magnus*. I have no specimens.

Subfamily ROMALEINAE

THE GENERA (AND SPECIES) OF ROMALEINAE KNOWN TO OCCUR IN NEVADA

Winged ..... *Tytthotyle maculata*
Wingless ..... *Tanaocerus koebelei*

This subfamily contains species commonly known as "lubbers," and occasionally of some economic importance on the open range. Only the above-listed species are known for Nevada.

64. TYTTHOTYLE MACULATA (Bruner) 1889 (*Thrincus* (?)).

CLARK COUNTY (*Keystone Cañon* (Spring Mts.) 3(VI)37, el. 4800 ft. –LaR & Hancock).

This large, handsome species is common in southern Nevada, and is a strong flier. Many specimens taken were heavily infested with mites whose favorite spot is beneath the wing insertions, where they often cluster in considerable numbers. Rehn and Hebard (1909) wrote of it: "This peculiar locust was taken at three localities, and in every instance it frequented volcanic rock fragments, flying long distances, somewhat like species of the genus Schistocerca, alighting precipitately on the bare volcanic rocks, and almost invariably climbing upon one of the higher fragments. The insects were, however, easily approached when due caution was used."

"The series comprises six males and two females, taken as follows: . . . foothills Bird Spring Mountains, August 11" (1907), "four males, one female, specimens being taken in both California and Nevada."

65. TANAOCERUS KOEBELEI Bruner 1906.

Ball et al. (1942) lists the species from "Charleston Peak, Indian Springs" (Clark County), "and Beatty" (Nye County), "Nevada; . . . (Tinkham)." In 1947, Tinkham listed several additional localities within a 50-mile radius of Las Vegas, Nevada (Clark County) as well as reiterating the Beatty locale. I have no specimens.

Tinkham's observations on the species are of timely interest to this report. He considers the species as restricted to the "Nevada Desert subtype" (see *Trimerotropis arizonensis*).

"Although rare, nymphs of *Tanaocerus* can be found in the fall by diligent searching. However by spring when the species has become mature, specimens are exceedingly rare, probably the price paid for the precariousness of desert existence. In the fall, collections revealed a preponderance of female to male nymphs. By spring, only a few females survive; males are apparently wanting since long and diligent searching failed to discover any. The only known adult male was taken by the author in the Gila Mountains in December 1940.

"As the nymphs are present in October, the eggs undoubtedly hatch during the late summer rains in late August or early September. The nymphs mature in late December or January and live until April. The desert heat probably kills them off before mid-May as repeated attempts over broad expanses of the desert at this time failed to reveal any specimens.

"The tiny male is a remarkable jumper but unlike other acridids which leap horizontally, it springs vertically into the air in high curving loops. The nature of these leaps apparently enable the male to eventually land on the top of a clump of its host plant *Franseria dumosa* which is found scattered every few feet in its desert environment. The male is almost impossible to follow or catch. The female is soft-bodied and sluggish with its saltatorial ability reduced—being able to jump only one to two feet. The nymphs are found at night perched on the top twigs of its host plant and occasionally on other desert plants. During the day the nymphs often wander a few feet away from the host plant on foraging trips.

"Its favorite habitat appears to be stony or gravelly soil on the desert mesas where *F. dumosa* is usually codominant with *Larrea* the Creosote bush" (1947).

Tinkham also lists *Hymenoclea salsola* and *Coleogyne ramosissima* as hosts. I have no specimens.

Subfamily CYRTACANTHACRINAE (Acridinae)

GENERA OF CYRTACANTHACRINAE KNOWN, OR LIKELY, TO OCCUR IN NEVADA

1. Body very long and slender 2
—Body normal in proportions 5
2. Wings not attaining abdominal tip 3
—Wings attaining or exceeding abdominal tip 4
3. Antennal base an eye-width in front of the front margin of the eye; ♂ ♂ subgenital plate long and narrow; antennae more than one-half inch long ..... (*Prorocorypha*)
—Antennal base closer to front eye margin; ♂ ♂ subgenital plate short; antennae less than one-half inch long ..... *Parapomala*
4. Prosternal spine faint or absent ..... *Eremiacris*
—Spine subcircular in outline conical, with flattened apex ..... *Leptysma*
5. Tegmina narrow, elliptical; frontal costa strongly and convexly bowed in front of eyes ..... (*Clematodes*)
—Tegmina in the form of long or short oval pads; frontal costa not bowed out, the fastigium rounding evenly into frontal costa and face 6
6. ♂ ♂ subgenital plate with deep apical cleft; size large, with long wings ..... *Schistocerca*
—♂ ♂ subgenital plate not cleft 7
7. Wings completely absent ..... *Bradynotes*
—Wings present 8
8. Wings well-developed, attaining or exceeding abdominal tip 9
—Wings reduced to non-functional pads 13
9. Prosternal spine transverse in ventral view ..... (*Aidemona*)
—Spine conical 10
10. Body color bright green with white dorsal stripe on pronotum and white lateral patches on thorax; tegmina bluish-green, with very narrow white stripes ..... (in part) *Hesperotettix*
—Color not as above 11
11. Tegmina pale greenish; pronotum and caudal femora bluish-green marked with red and yellow, profusely spotted with white, blue and black dots ..... *Poecilotettix*
—Tegmina and body darker, grayish or grayish-brown 12
12. Subgenital plate of ♂ ♂ with a subapical cone ..... (in part) *Acoloplus*

—♂ ♂ plate without an apical cone or point ..... (in part) *Melanoplus*
13. Color bright, deep purplish-blue marked with red ..... (*Dactylotum*)
—Color not as above 14
14. Body color greenish 15
—Color darker 17
15. Caudad pronotal margin straight; body color deep foliage green with brilliant crimson-red stripe on head and pronotum ..... (*Perixerus*)
—Caudad pronotal margin angulate or convex caudad 16
16. Caudad pronotal margin angulate; body bright green with full-length dorsal white stripe; pronotal sides with black patch ..... (in part) *Hesperotettix*
—Pronotal margin convexly-rounded caudad; body uniformly greenish without stripes ..... (in part) *Aeoloplus*
17. Pronotum with distinct lateral keels ..... *Oedalecnotus*
—Pronotum without keels 18
18. Caudad pronotal margin slightly concave cephalad ..... (*Conalcea*)
—Pronotal margin slightly angulate caudad 19
19. Head excessively large in proportion to pronotum ..... (*Phoetaliotes*)
—Head normal in size ..... (in part) *Melanoplus*

66. LEPTYSMA MARGINICOLLIS (Serville) 1839.

Ball et al. (1942) list this from: "Bunkerville, Nevada (Ball)" (Clark County). I have no specimens.

67. EREMIACRIS PALLIDA (Bruner) 1904 (*E. dissimilis* (Bruner) 1904, *E. perpallida* (Rehn & Hebard) 1908; *Parapomala*).

CLARK COUNTY (*Las Vegas* 10(VIII)07, el. 2250 ft. –R & H) (Rehn and Hebard 1909); 31(VII)30. E. R. Tinkham) (Tinkham 1938).

Rehn and Hebard (1909) wrote of the species: (taken) "in the foothills of the Bird Spring Mountains, California and Nevada, at Lyons, Nevada, and Las Vegas, Nevada."

"Grassy spots in the desert were the haunts of the insect at Las Vegas. . . . The series from the Bird Spring Mountains and Las Vegas exhibit a considerable amount of individual variation in size in the female sex, the specimens measured being nearer the maximum size in each lot. . . . The Cottonwood" (Arizona) "and Lyons females are in the greenish phase, but the color is decidedly yellowish with a suppression of the lateral bars, which latter is absolute in all the Bird Spring Mountains females and several from Las Vegas, Three of the Bird Spring Mountains females are uniform gall stone yellow, the other one uniform light green with the tegmina yellowish and antennae brownish. One of the Las Vegas females is similar to the latter, and another from the same locality closely approaches it. Two of the Las Vegas females are light brownish much suffused on the head, pronotum and caudal limbs with hoary white, the lateral bars very weak in two specimens."

Tinkham's record is of two specimens taken at light at night. I have no specimens.

68. EREMIACRIS ACRIS (Rehn & Hebard) 1908 (*Parapomala*).

CHURCHILL COUNTY (*Allen Spring* 25(VIII)46, el. 4500 ft. –LaR; *Rawhide Sands* 26(VIII)46, el. 4200 ft. –LaR).

This very slender, greenish species I have only from a restricted area in the hills south of Fallon. At the Allen Spring locality, it was not uncommon in alfalfa (*Medicago sativa*) growing wild along a tiny streamcourse which originated in boiling springs a few hundred feet away and finally disappeared in the alkaline ground a bit farther on. Some were also taken in *Distichlis spicata* (saltgrass). At the Rawhide Sands locality, four miles directly south-southeast in an adjacent valley, the species' habitat was that of a typical sand dune area, where it seemed to prefer sand bunch grass, *Oryzopsis hymenoides*.

69. SCHISTOCERCA SHOSHONE (Thomas) 1873 (*S. venusta* Scudder 1889; *Acridium*).

CHURCHILL COUNTY (*Fallon* 29(VIII)46, el. 4000 ft. –LaR); CLARK COUNTY (*Las Vegas* 10(VIII)07, el. 2250 ft. –R & H) (Rehn and Hebard 1909); WASHOE COUNTY (*Reno* (Truckee Meadows) 17(VI)40, 13(VIII)40, el. 4500 ft. –LaR).

The very common green garden and meadow species. Thomas (1873) wrote of the *shoshone* material: "The collection was chiefly made by Dr. Yarrow, who informs me that the specimens are mostly from southeastern Nevada and southwestern Utah." In 1880, Scudder wrote that "specimens taken at Reno, Nev., August 18, must be referred to this species, as a comparison with the types kindly lent me by Mr. Thomas, shows, but they have a distinct dorsal yellow stripe, probably effaced in Mr. Thomas's specimens from too long immersion in alcohol."

Rehn and Hebards' notation (1909) is: "Three males of this species were taken at Las Vegas . . . where the species was found in clumps of green weeds near water. The habits and habitat of this species seemed to be exactly the same as those of *Schistocerca venusta*, but we have never found the two at the same place.

"The only previous records of the species from Nevada are either indefinite or from the northern section of the State (Truckee Valley)."

Common associates are *Melanoplus femur-rubrum, M. packardi, Aulocara elliotti* and *Arphia pseudonietana*. One of our largest grasshoppers.

(SCHISTOCERCA VAGA (Scudder) 1876.

This species undoubtedly occurs in southern Nevada, being recorded from Boulder Dam, Arizona (Ball et al. 1942) across the State line, and is the only grey *Schistocerca* in the region).

(SCHISTOCERCA LINEATA Scudder 1899.

Like the preceding species, *S. lineata* is to be looked for in southern Nevada. Unlike *S. shoshone, S. lineata* always possesses a prominent, long yellow dorsal stripe, and is green with a definite brownish tinge).

70. AEOLOPLUS TENUIPENNIS Scudder 1897 (*Ae. uniformis* Scudder 1897, *Ae. oculatus* Scudder 1897, *Ae. arizonensis* Scudder 1898).

CLARK COUNTY (*Las Vegas* 10(VIII)07, el. 2250 ft. –R & H) (Rehn and Hebard 1909).

Scudder (1897) reported *Ae. uniformis* from "Truckee Valley, Nevada, R. Ridgway." Rehn and Hebard (1909) reported concerning *Ae. arizonensis*:

"This species appears to be the commonest one of the genus over a considerable extent of country, ranging from southeastern Arizona to southern Nevada and the Colorado Desert. The California and Nevada series before us consists of seventy-seven specimens distributed as follows: . . . Las Vegas, Nevada, August 10, ten males, twelve females. . . . The Las Vegas series, while showing the instability of the species in these two respects" (size and coloration), "averages smaller and is more uniform than the Indio series, which shows great diversity in both sexes.

"The Las Vegas series has rose purple or a shade of it the predominant color of the caudal tibiae, while the Indio series has glaucous the color : all the specimens."

The genus ranges from Creosote- to Shadscale-Zones, and is an inhabitant of chenopodiac stands, being recorded from *Sarcobatus vermiculatus* and various species of *Atriplex*, as well as Russian thistle (*Salsola kali tenuifolia*) (Hebard 1929), one, in fact, being described as *Ae. chenopodii*.

Tinkham (1938) records *tenuipennis* as coming to light at night "West of Jean on the California-Nevada line," 27(VI))32, –M. J. Oösthuizen (Clark County). I have no specimens.

71. AEOLOPLUS EREMIAPHILA Hebard 1919 (*Aeoloplides*).

LYON COUNTY (*Mason* 6(IX)10, el. 4600 ft. –R & H) (Hebard 1919).

Hebard also lists it from *Mina* and vicinity (Mineral County) without further data. Mason is the type locality. Hebard's comments (1919) are:

"The desert valley at Mina, 4800 to 5300 feet in elevation, with long and very gradual alluvial slopes running down into a large central playa, proved an area of scarce insect life. But, from the several species of dense and heavily thorned, leaf-less bushes on the slopes, three specimens of this species were secured after long and careful search. On the same day, three miles distant in the sterile and desert Pilot Mountains, three more specimens were taken. These were found in similar thorn bushes, scattered over the almost bare slopes at the foot of precipices and at the heads of cañons, at 5500 to 5700 feet. Great numbers of these bushes were examined, the only Orthoptera there found being the few specimens of the present species, *Ligurotettix coquillettei* McNeill in moderate numbers, and a single specimen of a Decticid which has as yet not been studied.

"Two days later at Mason, in a generally similar area and from similar but heavier thorn bushes, five more individuals were secured, at elevations from 4500 to 5200 feet in the foothills of the Singatse Range. The most successful method of capturing these specimens was to tramp down the brittle thorn bushes, in which case individuals of *Ligurotettix coquillettei* McNeill would fly swiftly to other adjacent bushes, but those of the present species would appear confused and could be taken by exercising reasonable caution. When this method was not followed, these little insects were found to slip about in the dense twigs and thorns with great agility and would occasionally disappear, leaving the pursuer baffled, with hands usually well scratched."

72. OEDALEONOTUS ENIGMA (Scudder) 1876.

WASHOE COUNTY (*Reno* (Truckee Meadows) 28(V)40, 27(VI)40, el. 4500 ft. –LaR).

This medium-sized brachypterous species is common about Reno. According to Scudder (1897): "Bruner reports the species also from Nevada" etc. Hebard (1935B) mentions specimens from Carlin (Elko County), Nevada.

73. OEDALEONOTUS BORCKI ORIENTIS Hebard 1920.

CLARK COUNTY (*Lee Cañon* (Spring or Charleston Mts.) 18–21(VIII)19, el. 6000 to 8500 ft. –R & H); ELKO COUNTY (*Ruby Mountains* (north foothills) 18(IX)19, el. 5800 ft. –Hebard); LINCOLN COUNTY (*Crestline* 4(IX)09, el. 6000 ft. –R & H) (Hebard 1920). Lee Cañon is the type locality. I have no specimens.

Some of Hebard's comments (1920) are: "In the Spring Mountains, this insect occurs through the zone of juniper and pinyon and well up into the zone of the bull pine (*Pinus ponderosa douglasi*). It reached its greatest numerical abundance, being moderately numerous and widely distributed, in the sparse grass and low green plants growing on pebbly soil at 7000 to 7200 feet, where the junipers and pinyons also reached their optimum development. At Crestline it was very scarce, the specimens being found singly and widely scattered, occurring in areas where a low yellow-flowered composite and sage brush grew among the scattered junipers and pinyons. The single individual taken at the foot of the Ruby Range was found under conditions similar to those at Crestline."

74. HESPEROTETTIX VIRIDIS NEVADENSIS Morse 1903 (*H. nevadensis termius* Hebard 1918).

WASHOE COUNTY (*Cold Spring* (Lawton Valley) near Reno 11(VII)46, el. 4600 ft. –LaR & Christensen; *Reno* (Truckee Meadows) 7(IX)40, 24(VIII)41, el. 4500 ft. –LaR).

Common in the vicinity of Reno. Morse's type specimens came from "Ormsby Co., Nev., July 6" (C. F. Baker). In 1918, Hebard described *H. nevadensis termius* from *Crestline* and *Caliente* in Lincoln County, then in 1930 replaced *nevadensis* as a variety of *viridis*. His 1918 remarks concerning *H. n. termius* are pertinent:

"The species was found very scarce in weedy areas of valley bottoms at Milford" (Utah) "and Caliente, particularly in a yellow-flowered, feathery, green plant of the daisy family, growing solidly waist-high over large areas. Every effort was made to secure a good representation, the material being obtained by long and continuous beating. Earlier in the season the insect is probably more numerous."

75. HESPEROTETTIX FESTIVUS Scudder 1898.

CLARK COUNTY (*Las Vegas* 10(VIII)07, el. 2250 ft. –R & H) (Rehn and Hebard 1909).

Their notation is: "The green of the Las Vegas series is pale and decidedly yellowish, all from that locality being uniformly colored." I have no specimens.

76. MELANOPLUS HERBACEUS Bruner 1893 (*M. flavescens* Scudder 1897, *M. browni* Caudell 1902).

CLARK COUNTY (*Las Vegas* 10(VIII)07, el. 2250 ft. –R & H) (Rehn and Hebard 1909).

They noted: "A pair of this species was also taken on vegetation on irrigated land. . . . This is one of the most active species of the genus *Melanoplus*.

"The species has previously been recorded from California at San Diego and Indio, this constituting, however, the first Nevada record." I do not have the species.

77. MELANOPLUS BIVITTATUS (Say) 1825 (*M. femoratus* (Burmeister) 1838; *Caloptenus, Pezotettix*).

WASHOE COUNTY (*Reno* (Truckee Meadows) 19–23(VI)40, 17(VIII)40, el. 4500 ft. –LaR); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 19(VII)39, el. 7800 ft. –T. O. Thatcher; *Shoshone* 11(IX)46, 4500 ft. –Christensen).

The largest of my Nevada *Melanopli* (= *Melanoplus* only, not MELANOPLI as generally used in its widest sense; this older, more inclusive term should be replaced by the standardized MELANOPLINI), a somewhat lubbery meadow inhabitant. Scudder (1897) says Riley recorded it from Nevada.

78. MELANOPLUS DIFFERENTIALIS NIGRICANS Cockerell 1917 (*Caloptenus, Pezotettix*).

CLARK COUNTY (*Logandale* 16(V)39, el. 4400 ft. –LaR); LINCOLN COUNTY (*Hiko* 12(VIII)40, el. 3800 ft. –LaR).

Previously reported from Nevada by Riley (fide Scudder 1897). This large species is known to me only from extreme southern Nevada where it is not uncommon in cultivated areas. Hebard (1925) wrote: "It is apparently largely absent from the Great Basin, but occurs as far west as Grand Junction, Colorado and Albuquerque, New Mexico."

79. MELANOPLUS DEVASTATOR Scudder 1878 (*M. virgatus* Scudder 1897).

DOUGLAS COUNTY (*Genoa* 7(VIII)46, el. 4600 ft. –LaR & Trelease); WASHOE COUNTY (*Reno* (Truckee Meadows) 9(VI)40, el. 4500 ft. –LaR; *Steamboat Springs* (Truckee Meadows) 22(VIII)46, el. 4600 ft. –LaR).

Scudder (1880) reported it from "Reno, Glen Brook, and Lake Tahoe, Nev." In 1891, Bruner wrote: "it . . . is injurious in Nevada, California, Arizona and Oregon." It is still occasionally of economic importance in local areas in western Nevada where it is confined to the vicinity of luxuriant meadow bottomlands, associated with *Dissosteira carolina, Arphia pseudonietana* and *Melanoplus packardi*.

80. MELANOPLUS MEXICANUS (Saussure) 1861 (*M. spretis* (Thomas) 1864, *M. spretus* (Walsh) 1866, *M. atlanis* (Riley) 1875, *M. intermedius* Scudder 1897; *Caloptenus*).

CHURCHILL COUNTY (*Allen Spring* (22 miles S of Fallcn) 25(VIII)46, el. 4500 ft. –LaR); LANDER COUNTY (near *Hilltop* (2(VII)41, el. 6000 ft. –LaR & Christensen); LINCOLN COUNTY (*Pahranagat Valley* (Alamo) 15(V)40, 12(VIII)40, el. 3800 ft. –LaR); LYON COUNTY (*Wellington* 27(VIII)46, el. 4500 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 23(V)40, 30(IX)40, 27(IX)41, el. 4500 ft. –LaR; *Verdi* 6(VIII)40, el. 4750 ft. –LaR).

A common Nevada species. Scudder (1880) reported *atlanis* from "Glen Brook, Nev." The migratory phase of *mexicanus* has long been known in the literature as *spretus*. Packard (1877) published the following observations communicated to him in a letter by Cyrus Thomas, which is reiterated here since it furnishes some valuable data on the early distribution of the species in Nevada:

"I saw *C. spretus* in 1871 in abundance along the Humboldt River in Nevada, most of the way from where the Central Pacific Railroad strikes it (going west) to the sink or place where it disappears. At one point they were quite abundant, and evidently preparing to migrate, flying up in the air, their wings presenting that peculiar glassy, snowy appearance with which you are no doubt familiar. This, if I recollect rightly, was west of Humboldt Station; they were quite abundant at that station (Humboldt), where we dined, (going west), but were not migrating there or then; those referred to as seen west of Humboldt being seen as we returned east. You probably remember that saline or alkaline belt at the northwest extremity of Great Salt Lake; just beyond that I began to observe them, and from then—not continuously, but at certain points—from there to, and a short distance west of, Humboldt Sink. The collections made by Wheeler's party in Southeast Nevada had no specimens which I could positively say came from that section. That year (1871), as we went out (June), we saw but few specimens in Salt Lake Valley, but they were quite numerous when we returned from California in August. They were also numerous in Caché Valley" (Utah) "and southern Idaho; in moderate numbers west of the range in Montana as well as east."

Packard continues: "From the facts thus afforded by Professor Thomas, it is not improbable that this species in its normal form will be found to commonly occur in the treeless regions of the entire State of Nevada . . . when the rain-fall is very considerable, and the land clothed with forests, we are to look for the non-migratory variety, *Atlanis* . . ."

My own collecting experience in Nevada indicates that *mexicanus*, while commonly met as individuals, are not so common in bands; in contrast, the omnipresent *occidentalis* is not only found everywhere one looks in Nevada today, but forms extensive bands which come as close to actually blanketing a countryside as is possible without becoming epidemic. Except for the fact that *occidentalis*, in my experience, is non-migratory and does not move in, particularly, on agricultural areas, confining its depredations to the open range, there is nothing to distinguish sight records of this species from similiar observations of the swarming of the migratory phase of *mexicanus*. And while it

is non-migratory, at the season of swarming, the air as high as vision can probe is often alive with *occidentalis*, giving every appearance of a swarm about to move. Since environmental conditions have not changed materially since the elder entomologists' pioneer observations of *mexicanus* in Nevada, I am inclined to the belief that many of the published accounts of this species were actually based on sight records of swarming *occidentalis*—Cyrus Thomas, for instance, made many of his observations from a Central Pacific railroad coach over large parts of Nevada, from which situation the two species could not be differentiated between in the air.

At the Hilltop locality, *mexicanus* was found in large numbers. Unlike *occidentalis*, *mexicanus* when flushed invariably dived headlong for the protection of surrounding weeds and bushes. Individuals were most commonly found on such vegetation, leaving the clearings largely to *occidentalis*. As *M. spretis*, Rehn and Hebard (1906) reported the species up to an altitude of nearly 10,000 feet in the Colorado Rockies.

—MELANOPLUS MEXICANUS BILITURATUS (Walker) 1870 (*Caloptenus*).

Scudder (1897) listed this from "Ruby Valley, Elko County, Nev., R. Ridgway; Camp Halleck, Elko County, Nev., E. Palmer; Reno, Washoe County, Nevada (USNM—Riley Collection); Truckee Valley, Nevada, R. Ridgway; Lake Tahoe, Nev., Packard." At best, *bilituratus* is only a weak form, and may revert to synonymy. Rehn and Hebard (1906), speaking of specimens from the vicinity of Salt Lake City: "This is the first record of this species from Utah, and the first one east of Fort Halleck, Elko Co., Nevada. . . ." I have no specimens referrable to this form.

81. MELANOPLUS OCCIDENTALIS (Thomas) 1872 (*M. flabellifer* Scudder 1879, *M. cuneatus* Scudder 1897; *Caloptenus, Pezotettix*).

EUREKA COUNTY (*Beowawe Hot Spring* 25(VI)41, el. 4700 ft. –LaR & Christensen); HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) (31(VII)46, el. 4800 ft. –LaR); LANDER COUNTY (near *Hilltop* 2(VII)41, el. 6000 ft. –LaR & Christensen); MINERAL COUNTY (*Walker Lake* (south end) 7(VII)41, el. 4050 ft. –LaR & Christensen); PERSHING COUNTY (*Humboldt Queen Cañon* (Humboldt Range) 1(VIII)46, el. 4100 ft. –LaR; *Nightingale Range* (west side 23–24(VII)46, el. 4500 ft. –LaR); WASHOE COUNTY (*Cottonwood Cañon* (Peavine Mountain) (near Reno) 22(VI)46, el. 5500 ft. –LaR & Christensen; *Pyramid Lake* 19–20(VI)46, el. 3850 ft. –LaR & Christensen).

In my experience, this common species is the strongest flier of the genus in Nevada, staying in the air for long periods and often rising above the collector's visual range. At the Hilltop locality, *occidentalis* seemed to prefer the road and other clearings along cañon bottoms, and if flushed, flew to another open spot instead of seeking sanctuary in dense vegetation as was the habit of *M. mexicanus*. During hot summer noons, thousands of *occidentalis* could be seen flying sedately overhead at barely visible heights, while the hum of their wings was one of the characteristic sounds of this part of the day. Descending to the flat into which Hilltop cañon empties, it was necessary to close all car windows in order to drive safely through the hordes of flying *occidentalis*. Similar conditions prevailed in 1946 and 1947 at the Pyramid

Lake locality; adjacent to Pyramid Lake, on the east face of the Lake range bordering Winnemucca Sink, the owner of a small place claimed that his vegetable garden was apparently not especially attractive to the hordes of *occidentalis* occupying the range about him, who seemed to prefer their natural forage of largely bitter desert plants. Other species of *Melanopli* in similar numbers, would have literally "wiped him out." This behavior seems more-or-less typical of *occidentalis* as I have observed them in other parts of the state.

In October of 1941, several *occidentalis* were found caught in webs of the very common large orb weaver *Neoscona vertebrata* which literally blankets the shores of Pyramid Lake with its webbing wherever suitable stands of dead weeds are available. Although *occidentalis* is largely through swarming by the time the year's crop of *N. vertebrata* approaches maturity, enough remain in late summer and autumn to furnish considerable food for the spiders. Large numbers of *occidentalis* were drowning in waters on the east side of Pyramid Lake during the 1946 swarming. I have also found them out prowling the extensive south dunes of Pyramid Lake long after dark, and in considerable numbers, while collecting for tenebrionids; these evidently represent individuals stranded on the vegetationless areas of the dunes by nightfall.

In a comment on the species' vertical distribution, Rehn and Hebard (1906) wrote: "The species has been recorded by Gillette from localities up to an altitude of 8000 feet and in view of the Pike's Peak records here given it will be seen to extend to an elevation of at least 10,500 feet, and to be truly an alpine species.

"From the material collected this species appears to frequent a variety of habitats, from a distinctly arid region at Emigrant to a grassy gully in the Garden of the Gods" (Colorado). "On the whole this form frequented the more sterile sections of the regions in which it was collected."

82. MELANOPLUS FEMUR-RUBRUM (DeGeer) 1773 (*M. arcticus* (Walker) 1870, *M. plumbeus* (Dodge) 1877, *M. coloradus* Caudell 1903; *Caloptenus, Pezotettix*).

CHURCHILL COUNTY (*Fallon* 14(XII)40, el. 4000 ft. –LaR; 29(VIII)46, –LaR); LYON COUNTY (*Wellington* 27(VIII)46, el. 4500 ft. –LaR; *Yerington* 28(VIII)46, el. 4400 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 16–27(V)40, 9(VII)40, el. 4500 ft. –LaR); WHITE PINE COUNTY (*Ely* 11(IX)46, el. 6470 ft. –Christensen; *Lehman Caves National Monument* (near Baker) 24(VII)39, el. 7800 ft. –T. O. Thatcher; *Shoshone* 11(IX)46, el. 4500 ft. –Christensen).

This common omnipresent species is habitually fond of meadowlands in the vicinity of Reno, and is occasionally of economic importance to cultivated crops, but has never been a major problem in Nevada. It has been recorded from Nevada by Scudder (1880) at "Glen Brook." At the Yerington locality, *femur-rubrum* and *Aulocara elliotti* were equally common and seemed to have much the same habits, preferring grass and weeds bordering well-irrigated fields. Rehn and Hebard (1906) have recorded the species up to 9000 feet in the Colorado Rockies.

83. MELANOPLUS COMPLANATIPES CANONICUS Scudder 1897.

CHURCHILL COUNTY (*Rawhide Sands* 25–28(VIII)46, el. 4200 ft. –LaR; *Sand Spring dune* 30(VII)46, el. 4500 ft. –LaR); CLARK COUNTY (*Bird Spring Mountains* 11(VIII)07, –R & H) (Rehn and Hebard 1909); HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 31(VII)46, el. 4800 ft. –LaR); MINERAL COUNTY (*Lucky Boy Mine* (S of Hawthorne) 5(IX)46, el. 5500 ft. –LaR & Gibson; *Walker Lake* (south end) 27(VIII)46, el. 4200 ft. –LaR); WASHOE COUNTY (*Long Valley* (near Reno) 9(VIII)40, el. 4500 ft. –LaR; *Reno* (Truckee Meadows) 25(V)40, 17(VI)40, el. 4500 ft. –LaR).

A rather common species, in my experience. Scudder (1880) had it, as *M. cinereus*, from "Reno, Nev." and in 1897 wrote: "I have found this insect only upon the sage brush (Artemisia), and so completely do its gray and rusty colors harmonize with its surroundings that it is extremely difficult to detect when at rest . . ."

"Coquillett remarks upon the ease of its flight, describing it as in a straight line, for a distance of from 5 to 20 feet from the ground." In addition to sagebrush (*Artemisia tridentata*) I have taken it on *Chrysothamnus* (Rabbitbrush), *Oryzopsis hymenoides* (Sand bunchgrass), *Dalea polyadenia* and several other unidentified sucullent sand dune plants. While it has a considerable distribution in sagebrush areas, I have found it in swarming condition only in the vicinity of sanded regions, particularly active dunes. When disturbed, *complanatipes* flies to an adjacent bush or plant, making it non-stop if the distance is only a matter of a few feet; if the distance is greater, the insect usually alights on the ground and almost immediately flies off again to sanctuary long before the collector can get within disturbing range again. At several sand dune localities, large series could be obtained by merely sweeping a net rapidly in front of the collector while walking through the insects.

Rehn and Hebards' 1909 note on the species is: "Three males and one female from Cottonwood" (California), "September 9, and one female from the foothills of the Bird Spring Mountains, Nevada, August 11, are inseparable from this species, previously known only from Cape San Lucas, Lower California, and Sonora, Mexico."

84. MELANOPLUS PACKARDI Scudder 1878.

CHURCHILL COUNTY (*Fallon* 29(VIII)46, el. 4000 ft. –LaR; *Rawhide Sands* 28(VIII)46, el. 4200 ft. –LaR); DOUGLAS COUNTY (*Genoa* 6(VIII)46, el. 4600 ft. –LaR & Trelease); HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 31(VII)46, el. 4800 ft. –LaR); LYON COUNTY (*Yerington* 28(VIII)46, el. 4400 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 20(VI)40, 17(VIII)40, el. 4500 ft. –LaR); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 8-9(VII)39, el. 7000 ft. –T. O. Thatcher).

Scudder (1897) listed it from "Ruby Valley, Nevada, R. Ridgway." This large, tan species is an habitué of well-watered roadsides and meadows, where its common associates are *Arphia pseudonietana, Melanoplus femur-rubrum, Aulocara elliotti* and occasionally *Conocephalus fasciatus vicinus*. In 1925 and 1928, Hebard re-mentioned the eastern Nevada occurrence as "the Ruby Range in Nevada. . . ."

85. MELANOPLUS FOEDUS Scudder 1879.

According to Scudder (1897) "it is said by Bruner to be found also in Nevada. . . ." I have no specimens.

86. MELANOPLUS LEPIDUS Scudder 1897.

Reported by Scudder (1897) from "Humboldt River, Nevada, August, S. W. Garman (MCZ); mountains near Lake Tahoe, California, October 14, H. W. Henshaw, Wheeler's Expedition, 1876; Truckee, Nevada County, California, October 10." I do not have the species.

87. MELANOPLUS ARIDUS (Scudder) 1879.

WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 7–28(IX)39, el. 7000 ft. –T. O. Thatcher).

The species was described from Arizona material. Rehn and Hebard (1909) wrote, with regard to adjacent California individuals: "The specimens were taken in the tree yucca area where they were scarce" (Cima). "They were found in a hilly location inhabiting the lowest bushes." I do not have the species.

(MELANOPLUS PACIFICUS (Scudder) 1881.

In 1909, Rehn and Hebard wrote: "The previous records of this species" (in California) "are from . . ." (the) "mountains near Lake Tahoe, California." Search will probably reveal the species on the Nevada side of the line).

88. BRADYNOTES OBESA (Thomas) 1872 (*B. compacta* Morse 1903).

HUMBOLDT COUNTY (*Paradise-National Summit* (Santa Rosa Mts.) 22(VI)41, el. 7600 ft. –LaR & Christensen); ORMSBY COUNTY (*5 mi. N. of Glenbrook* (Lake Tahoe) 16(VII) 46, el. 7000 ft. –LaR).

Morse (1903) described *compacta* from "Ormsby Co., Nev., July 6" (C. F. Baker) and commented: "Nearly allied to *B. obesa.*" This entirely wingless species, chunky and rather clumsy, I have taken only at elevations of 7000 feet or more. In addition to its northern Nevada occurrences, I have it from the High Sierras of adjacent California, at altitudes between 7000 and 8000 feet. My remarks on the status of Morse's name under *Chorthippus longicornis* apply equally to this situation.

Scudder (1897) listed *B. obesa* from the "Humboldt River, Nev., August, S. W. Burrison (S. Henshaw)." Without further explanation, Hebard (1928) wrote: "Scudder's records from California and Nevada, however, are incorrect, not applying to this species, and *obesa* is actually much less widely distributed and less common than that author supposed."

89. BRADYNOTES PINGUIS Scudder 1897.

WASHOE COUNTY (*Reno* (Truckee Meadows) 16(V)40, el. 5000 ft. –LaR).

A very common species in the sagebrush country about Reno. Scudder (1897) recorded it from "Reno, Nev., Hillman (L. Bruner)."

90. POECILOTETTIX SANGUINEUS Scudder 1897.

MINERAL COUNTY (*Walker Lake* (NE edge) 26(VIII)46, el. 4200 ft. –LaR).

I have taken this beautifully-marked species only on *Ephedra* and *Chrysothamnus* at the indicated locality, where its habits are much those of associated *Melanopli*, chief of which is *M. complanatipes*. Also common to the same environment are the oedipodines *Trimerotropis caeruleipennis* and *T. pallidipennis*. Ball et al. (1942) mentions "Nevada" as part of its range.

Superfamily TETTIGONIOIDEA

THE FAMILIES OF TETTIGONIOIDEA KNOWN TO OCCUR IN NEVADA

1. Tarsi 3-segmented, or less ..... (true crickets) Achetidae
—Tarsi 4-segmented 2
2. Wings present; front tibiae with an auditory organ ..... (katydids) Tettigoniidae
—Wings absent; no auditory organ on front tibiae ..... (ground-, cave-, camel-crickets) Gryllacrididae

Family TETTIGONIIDAE

THE SUBFAMILIES OF TETTIGONIIDAE KNOWN TO OCCUR IN NEVADA

1. First two tarsal segments lacking a lateral groove; posterior margin of hind tibiae with its two series of spines continued to tibial apex ..... Phaneropterinae
—First two tarsal segments with lateral groove; spine series not continued to tibial apex 2
2. Fore tibiae with a dorsal apical spine on the outer side; wings generally vestigial ..... Tettigoniinae
—Fore tibiae without dorsal apical spines; wings well developed 3
3. Fore and middle femora spined beneath; vertex of head produced into a long, sharp cone ..... Copiphorinae
—Fore and middle femora unarmed beneath; vertex terminating in a rounded tubercle which is hollowed out on the sides ..... Conocephalinae

Subfamily PHANEROPTERINAE

THE GENERA OF PHANEROPTERINAE KNOWN, OR LIKELY TO OCCUR, IN NEVADA

1. Fore coxae unarmed; antennae very long (wings short; color brown) ..... (*Dichopetala*)
—Fore coxae armed with a spine; antennae only moderately long (wings usually long, color usually green) 2
2. Pronotum saddle-shaped; size small, less than 1½ inches long 3
—Pronotum not saddle-shaped; size large, more than 1½ inches long 4
3. Dorsal abdominal segments with margins straight or crenulate; hindwings less than ¼ inch longer than forewings; comparatively robust, usually found in trees and bushes ..... *Insara*
—Dorsal abdominal segments with margins angularly produced rearward in the center; hindwings more than ¼ inch longer than forewings; slender and long-legged, usually found in grass and low plants ..... *Arethaea*
4. Forewings only slightly wider at middle than at apex; fastigium between antennae only slightly wider than first antennal segment ..... *Scudderia*
—Forewings distinctly wider at middle than apex; fastigium much wider than first antennal segment 5
5. Ovipositor short, abruptly bent upwards; metasternal lobes elongate; hind femora short, less than 2/3 as long as tegmina ..... (*Microcentrum*)

—Ovipositor long, gently-curved; metasternal lobes rounded; hind femora nearly as long as tegmina ..... (*Amblycorypha*)

91. INSARA ELEGANS CONSUETIPES (Scudder) 1900 (also *Arethaea*).

CLARK COUNTY (*Las Vegas* 2(IX)09, el. 2250 ft. –R & H); LINCOLN COUNTY (*Caliente* 3(IX)09, el. 4400 ft. –R & H) (Rehn and Hebard 1914A).

Ball et al. (1942) mentions "Nevada" as part of the range. The above designation of "Las Vegas" is listed as "Lincoln County" by Rehn and Hebard. Since their early work in Nevada, the southern half of Lincoln County has been separated as Clark County. I have no specimens.

92. INSARA COVILLEAE Rehn & Hebard 1914.

CLARK COUNTY (*Porter's Well* (Dead or Newberry Mountains) 17(V)37, el. 800 ft. –LaR & Hancock); near *Lyons*, California 1(X)09, el. 2800–3000 ft. –R & H) (Rehn and Hebard 1914A).

The "Lyons" locality of Rehn and Hebard has been variously listed by them as "Lyons, Nevada," "Lyons, California," "Nevada, near Lyons, California," and "Lincoln County, near Lyons, California." It is apparently located in San Bernardino County, California, adjacent to the Clark County, Nevada, line, and I doubt if the name is being used at the present time.

This very typical Creosote Zone species was taken in a desert wash not far from the Rio Colorado (Porter's Well), coming readily to a Coleman lamp at night. Rehn and Hebard (1914A) took their specimens entirely by beating the creosote bush (*Larrea divaricata*) (*Covillea*). See *Arethaea brevicauda*.

93. ARETHAEA COYOTERO Hebard 1935.

LINCOLN COUNTY (*Crestline* 4(IX)09, el. 6000 ft. –R & H); NYE COUNTY (*Ash Meadows* 14–19(VIII)21, el. 2300 ft. –Knaus, Ninimger & Hoover; *Beatty* 12(VIII)19, el. 3300 ft. –Rehn) (Hebard 1935A).

The Lincoln County record was reported as *A. brevicauda*. Ball et al. (1942) mentions 'Nevada" as part of the range. I have no specimens.

94. ARETHAEA BREVICAUDA (Scudder) 1900 (also *Dichopetala*).

CLARK COUNTY (*Tule Spring* 30(VI)21. –O. C. Poling; (Hebard 1936); *Porter's Well* (Dead or Newberry Mountains) 17(V)37, el. 800 ft. –LaR & Hancock).

Associated with *Insara covilleae* and more abundant, being attracted to lights at night in large numbers. Like *Insara*, *Arethaea* is a slim, delicately-constructed and colored species. During the day, specimens were found hiding in the cooler depths of such plants as the omnipresent *Larrea divaricata*, *Krameria canescens*, *Prosopis juliflora* and *Acacia greggi*. Regularly associated with the *Insarae-Arethaea* attracted to night lights were the equally common *Litaneutria minor* and the bugs *Triatoma pallidipennis* and *Lygaeus lateralis*. Ball et al. (1942) list "southern Nevada" as part of the range.

(ARETHAEA POLINGI Hebard 1935.

This has been recorded from northwestern Arizona near the Nevada line (Ball et al. 1942), and is to be looked for in extreme southern Nevada).

95. SCUDDERIA FURCATA FURCIFERA Scudder 1898 (also *Phaneroptera*).

LINCOLN COUNTY (*Caliente* 3(IX)09, el. 4600 ft. –R & H) (Rehn and Hebard 1914A); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 5(VIII)37, el. 8000 ft. –T. O. Thatcher).

Hebard (1929) and Ball et al. (1942) repeated the above Rehn and Hebard record. I have no specimens. In 1923, Hebard listed the species in the genus *Phaneroptera*, following Caudell's previous selection of genotypes, but in 1931 reverted to *Scudderia* with the note: "We have discussed Caudell's genotypic selections and consequent use of *Phaneroptera* for this genus with a number of specialists who consider that his action is invalidated by Kirby's earlier publication. We therefore use *Scudderia* for the American genus concerned. An opinion on this situation by the International Commission should, however, be obtained."

(MICROCENTRUM RHOMBIFOLIUM (Saussure) 1859.

Listed by Ball et al. (1942) for vicinities adjacent to southern Nevada, and search will probably reveal its presence in the State).

Subfamily TETTIGONIINAE (Decticinae)

GENERA OF TETTIGONIINAE KNOWN, OR LIKELY TO OCCUR, IN NEVADA

1. Wings functional, longer than abdomen 2
—Wings non-functional, much shorter than abdomen 3
2. Prosternum unarmed; hind femora unarmed below ..... *Anoplodusa*
—Prosternum armed with a pair of spines; hind femora armed below on apical half with several distinct spines ..... *Capnobotes*
3. Prosternum armed with a pair of spines 4
—Prosternum unarmed 6
4. Lateral pronotal carinae present, sharp and distinct ..... (in part) *Aglaothorax*
—Lateral pronotal carinae faint or absent 5
5. ♂ ♂ tegmina longer than pronotum; pronotum saddle-shaped ..... *Zacycloptera*
—♂ ♂ tegmina less than ½ as long as pronotum; pronotum not saddle-shaped ..... (in part) *Eremopedes*
6. Lateral pronotal carinae indicated only by color, or entirely absent 7
—Carinae persistent except occasionally on the anterior fourth 11
7. Adult posterior femora less than twice as long as pronotum ..... (in part) *Anabrus*
—Adult femora more than twice as long as pronotum 8
8. ♀ ♀ fore tibiae rarely with more than one dorsal spine; lateral pronotal lobes not well-developed ..... *Ateloplus*
—Fore tibiae of both sexes with more than one dorsal spine; lateral pronotal lobes well-developed 9
9. ♀ ♀ tegmina projecting slightly beyond pronotum; ♂ ♂ tegmina projecting caudad ½ or more the length of the pronotum ..... *Idiostatus*
—♀ ♀ tegmina not projecting beyond pronotum; ♂ ♂ tegmina projecting rarely as much as ½ the length of the pronotum 10
10. Hind femora less than 2½ times as long as pronotum; posterior half of pronotum with distinct lateral and median carinae; size large, pronotum 12 mm. or more in length ..... (in part) *Anabrus*
—Hind femora more than 2½ times as long as pronotum; posterior half of pronotum without carinae; size smaller, pronotum 8 mm. or less in length ..... (in part) *Eremopedes*
11. Hind femora short, less than twice as long as pronotum 12
—Hind femora long, twice or more the length of the pronotum 13

12. Hind tibiae with two apical spines beneath; pronotum with low but persistent median carina; hind femora much swollen proximally, being more than twice as broad proximally as distally ..... (in part) *Aglaothorax*
—Hind tibiae with four apical spines beneath; pronotum with median carina distinct only posteriorly; hind femora less than twice as broad proximally as distally ..... (in part) *Plagiostira*
13. Hind femora approximately twice as long as pronotum; lateral prothoracic lobes perpendicular, or nearly so ..... (in part) *Plagiostira*
—Hind femora three or more times longer than pronotum; lateral lobes declivent 14
14. Median pronotal carina faint even posteriorly; lateral carinae bowed inward in the anterior half, posteriorly divergent, pronotal disk considerably broader behind than at the middle of the anterior half ..... (*Idionotus*)
—Median carina distinct and percurrent; lateral carinae parallel, sometimes slightly convergent in the anterior fifth, the disk little broader behind than elsewhere 15
15. ♀ ♀ tegmina forming slightly projecting lateral pads, widely separated above ..... *Steiroxys*
—Tegmina of both sexes well-developed, overlapping above and projecting about ½ the length of pronotum ..... (*Clinopleura*)

96. AGLAOTHORAX SEGNIS Rehn & Hebard 1920.

LINCOLN COUNTY (*Crestline* 4(IX)09, el. 6000 ft. –R & H) (Rehn and Hebard 1920).

This is the type locality, and the specimens were taken in *Juniperus utahensis*. I have not seen it.

97. AGLAOTHORAX ARMIGER Rehn & Hebard 1920.

CLARK COUNTY (*Charleston Peak Cañon* (Spring Mounatins) 15(VIII)31, el. 7500 ft.; *Mouth of Cañon* 20(X)39. –E. R. Tinkham) (Tinkham 1944); *Lee Cañon* Charleston Peak) 18–21(VIII)19, el. 4000–6000 ft. –R & H) (Rehn and Hebard 1920).

In this last, the type locality, the species was found in the Joshua tree (*Yucca brevifolia*) (*Clistoyucca*). Tinkham (1944) also lists *Pinus monophyla* as a common host. Known only from Nevada. I have no specimens.

(AGLAOTHORAX SIERRANUS Rehn & Hebard 1909.

Type locality.—Yosemite Valley, 4500 and 6000 feet elevations. A strong possibility for the Boundary Peak area of western Nevada).

98. ZACYCLOPTERA ATRIPENNIS Caudell 1907.

MINERAL COUNTY (*Thorne dune* 7(VII)41, el. 4600 ft. –LaR & Christensen; *Walker Lake* (south end) 14(VIII)38, el. 4100 ft. –E. R. & G. E. Tinkham) (Tinkham 1944).

The species was described from a solitary specimen from "Hawthorne, Nevada, June (Wickham)" (Caudell 1907) and is known only from the type locality. In discussing the species in 1944, Tinkham wrote: "This very large and rare creature is known only from the type locality, Walker Lake, Nevada. It is a member of the Great Basin Desert fauna. *Zycloptera*" (*Zacycloptera*) "*atripennis* is probably a relic of Pleistocene days when the Great Basin was a mass of great lakes. It survived to the present day probably because Walker Lake is the sole remnant of far larger lakes of the Pleistocene period in this region." He found it only on *Atriplex confertifolia* (shadscale)

and *Sarcobatus vermiculatus* (greasewood). My single ♂ specimen came from *Dalea polyadenia* on the small but distinctive Thorne dune, which lies in a pocket of the range bordering Walker Lake to the east not far from the southeast corner of the lake.

Intensive collecting may provide other Nevada records for the species. It seems restricted to the Big Greasewood—Shadscale association, or *Atriplico-Sarcobatetum*, and its related community, the Little Greasewood—Shadscale association (*Sarcobatetum baileyi*) as defined by Billings (1945); these are dominant over large areas of western, central and southern Nevada and *Zacycloptera atripennis* may have many suitable habitats in the area concerned. If the species is further restricted to dominant arenaceous regions, many such exist which might yield specimens with future collecting. It may very well be that Tinkham's suggestion of a relationship between Walker Lake as a remnant of Pleistocene Lake Lahontan and the species' present distribution is well-founded. I feel that such a thesis is more than suggested by the distribution and affinities of other Nevada species of my acquaintance, predominant among such being the newly-described tenebrionid *Lariversius tibialis* Blaisdell 1947.

99. CAPNOBOTES FULIGINOSUS (Thomas) 1872 (also spelled *Capnobates*).

CHURCHILL COUNTY (*Sand Spring dune* 5(VII)41, el. 4500 ft. –LaR & Christensen); CLARK COUNTY (*Keystone Cañon* (Spring Mountains) 3(VI)37, el. 4800 ft. –LaR & Hancock); MINERAL COUNTY (*Walker Lake* 14(VIII)38, el. 4050 ft. –E. R. Tinkham); STOREY COUNTY (*Virginia City* 28-31(VII)31, el. 6500 ft. –E. R. Tinkham) (Tinkham 1944).

I have found specimens of this large, strong flier resting and feeding on the common Creosote Zone shrubs *Fallugia paradoxa* and *Larrea divaricata*, as well as numerous shrubby asteracs. Its song, generally heard only at night, is weak and vacillating, and is difficult to track down if *Achetae* or *Oecanthi* are singing nearby. Caudell (1907) recorded the species for Nevada.

100. CAPNOBOTES OCCIDENTALIS (Thomas) 1872 (also *Capnobates*).

CHURCHILL COUNTY (*Sand Spring dune* 5(VII)41, el. 4500 ft. –LaR & Christensen); ELKO COUNTY (*Elko* 30(VI)41, el. 5000 ft –LaR & Christensen); MINERAL COUNTY (*Lucky Boy Mine* (near Hawthorne) 5(IX)46, el. 5500 ft. –LaR & Gibson); PERSHING COUNTY (*Nightingale Mountains* (west side) 23(VII)46, el. 4500 ft. –LaR); WASHOE COUNTY (*Peavine Mountain* (near Reno) 9(VI)40, 11–25(VII)40, el. 5000 ft. –LaR & Mahoney); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 5(VIII)37, 17(IX)39, el. 8000 ft. –T. O. Thatcher).

This species, smaller than *C. fuliginosus*, is a common *Artemisia* inhabitant about Reno; like its larger relative, it is a very weak singer, and extremely difficult to track down at night. Associated with it are species of *Oecanthus* and *Acheta* which often mask its presence. Caudell (1907) recorded a specimen from "Reno, Nevada (Wickham) taken in July." Tinkham (1944) listed juniper as its only host, but as stated above, it is common to sagebrush as well, and the Lucky Boy Mine specimen was taken on piñon pine. At the

Nightingale Mountains locality, I found the green phase on two species of introduced weed, *Salsola kali tenuifolia* and an unidentified chenopodiac, whose vivid greens the insect matched well. On sagebrush about Reno, I have taken only the dark phase.

The carnivorous propensities of the genus are well known. In the Nightingale Mountains locality, a green specimen was collected while feeding on a freshly-killed *Enallagma clausum* (Odonata). This damselfly was present in moderate numbers, despite the fact that the nearest possible breeding locality is ten miles due west in a tiny alkaline pond on the east flank of an adjacent mountain range. Five miles of this distance is occupied by the long, narrow Winnemucca Sink, an alkali flat devoid of water during summer and fall. In addition, the actual collecting spot was three miles up a winding cañon which contained no water. The nearest probable breeding area for odonates is Pyramid Lake, a massive desert lake some 20 miles to the west.

101. PLAGIOSTIRA GILLETTEI Caudell 1907.

CHURCHILL COUNTY (*Rawhide Sands* 26–28(VIII)46, el. 4200 ft. –LaR; *Sand Spring dune* 5(VII)41, el. 4500 ft. –LaR & Christensen; 29(VII)46. –LaR).

Described from western Colorado, and for many years unknown west of the type State. Its presence in Nevada is a considerable extension of the known range. It is a large, beautiful and extremely delicately-tinted animal; background color varies from a soft brown to an equally delicate green. The pronotal disc possesses from six-to-eight symmetrically-arranged white spots, the two posterior markings sometimes being absent. A similar series of white spots occurs along each side of the abdomen. The few specimens I have had in captivity proved as delicate in health as they were in coloration, all dying after short periods not exceeding three days. The species is undoubtedly hardier than this would indicate, since all captives were females taken after oviposition and very likely close to natural death.

My first specimens were taken on the lower reaches of the massive aeolian Sand Spring dune during the heat of midday, clinging near the tops of small, low clumps of sand bunchgrass, *Oryzopsis hymenoides*. Once located, several specimens were taken in rapid succession from nearly as many clumps of grass, the majority being females. On two instances, individuals were found feeding on the grass heads—the rest gave evidence of merely resting from the 120° sun; although directly in the sun's rays, their location several inches above the scorching sand undoubtedly made their situations tolerable. The second trip to the dune several years and over three weeks later in the season provided considerable biologic information. At this time, none could be found in the sand grass during the day, but at night a large number of oviposting females were found in the fine sandy soil surrounding the dune proper, no males being in evidence on the ground.

The eggs are 6.5 mm. x 1.5 mm. in size, white when first laid, then darkening slightly a few hours after oviposition. I was unable to find more than six eggs at any one oviposition site, and it may be that the species scatters a few eggs at each of many oviposition sites during the course of

egg-laying; the ground was fine and soft, and the long, decurved ovipositor apparently easily worked into position.

No nymphs were found at any time. The solitary male was located by following his song, which is very weak and vacillating much after the manner of *Capnobotes occidentalis*.

At the Rawhide Sands locality, *P. gillettei* was relatively common. The Sands are some twenty miles southwest of Sand Spring, and are much more extensive than the latter, occupying at the present time, a position straddling both slopes of a small east-west range. I found it impossible to approach the north portion to within reasonable walking distance, but was able to camp as close as a half-mile to the larger southern section. The first trip up on the western end of the Sands during late afternoon and early evening turned up a solitary male *gillettei* wandering about among a large stand of *Oryzopsis hymenoides;* he had a newly-healed wound on the abdomen and a hind tibia missing. The following morning, in the same vicinity, a freshly-dead female was found before a burrow of the common heteromyid rodent *Dipodomys merriami*. Fresh tracks were all around the insect, which was uneaten and had been apparently killed by a deep bite in the head.

A couple of days later, late afternoon collecting located a small colony of *gillettei* living in a vigorous stand of Russian thistle (*Salsola kali tenuifolia*). Lying in a low, east-facing depression, the plants were early shaded by the afternoon sun, and formed a congenial refuge. Both *P. gillettei* and the very abundant *Melanoplus complanatipes* were actively feeding on the succulent thistle, which in my experience, is a valuable supplement to the diet of many desert insects. Often, Russian thistle is the only plant still green by early fall in many desert areas, and from the variety of insects found feeding on it, is readily accepted as a food plant. Referring to *Aeoloplus turnbulli plagosus*, Hebard (1929) commented:

". . . this insect used to prefer *Atriplex*, but since the advent of the Russian thistle it is frequently present in large numbers on these plants. Though having unusual saltatorial development the species of this genus always seek safety in the nearest heavy brush or plant and the thickly meshed spiny twigs of the Russian thistle afford an ideal shelter."

Host plants as determined for *P. gillettei* are *Oryzopsis hymenoides, Atriplex canescens* and *A. confertifolia* (shadscale or saltbrush), and an unidentified *Chrysothamnus* (Rabbitbrush).

P. gillettei appear of mild temperament, unlike many other large tettigoniines, and made only feeble attempts to bite when handled freely. The species is now known from three general localities, each representing a single State, viz., extreme western Colorado, central Utah and western Nevada. Its distribution appears wide and discontinuous, but it will undoubtedly be found in suitable intervening areas, although I have so far been unsuccessful in locating it in what seem perfectly favorable localities in other parts of Nevada. Tinkham (1944) says "the species is also known from Nevada," but cites no specific records. His information is probably based on Nevada specimens in the collections of the Philadelphia Academy of Natural Sciences. To my knowledge, these have never been specifically reported, but were merely mentioned casually by Hebard (1929) as "Nevadan specimens."

102. ANABRUS SIMPLEX Haldeman 1852 (*A purpurascens* Uhler 1864, *A. coloradus* Thomas 1872, *A. similis* Scudder 1872, *A. maculatus* Caudell 1907, *A. nigra* Caudell 1907).

ELKO COUNTY (*Elko* 8(VII)39, el. 5000 ft. –LaR; *Jarbridge* (Jarbidge) 18(VI)39, el. 6350 ft. –LaR; *Midas* 12(VIII)39, el. 6500 ft. –LaR; *Mountain City* 26(VII)39, el. 5650 ft. –LaR; *Tuscarora* 8(VIII)39, el. 6500 ft. –LaR); EUREKA COUNTY (*Beowawe* 28(V)39, el. 4690 ft. –LaR); HUMBOLDT COUNTY (*Paradise Valley* 6(VI)36, el. 5500 ft. –LaR); LANDER COUNTY (near *Hilltop* 2(VII)41, el. 6000 ft. –LaR & Christensen); WASHOE COUNTY (*Lake Range* (north end) 16(V)40, el. 5000 ft. –LaR); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 8(VIII)38 ,el. 6000 ft. –T. O. Thatcher).

So much has been written of this famous species that little can be added in a faunal list of this nature. It occurs throughout the northern half of Nevada, often in enormous swarms, and has been a periodic economic problem since the original Mormon settlements in the Great Salt Lake Valley. Thomas (1875) said: "I can find but one specimen of this species in the collection made in Nevada;" (Wheeler's 1871-1874 U. S. Army 100th Meridian surveys) "but from Dr. W. I. Hoffmann's letter I presume they were seen in considerable numbers in central Nevada." Although northern Nevada farmers and ranchers cannot have failed to encounter cricket bands since the earliest days of settlement, it was not until 1878 that complaints from Tuscarora, Elko County, achieved official notice. Since then, man has been in constant warfare with the species which periodically builds up into bands of unbelievable numbers and large size, and sweeps over agricultural centers. In addition to its areas of regular endemicity, *A. simplex* occurs in many localities in insufficient strength to be rated a pest, so that its distribution is more extensive than its recorded depredations indicate. In contrast to most insects, which lack suitable common names, *A. simplex* has accumulated a variety of distinctive and apt designations, such as Mormon, Western, Great Plains, Idaho, Black, Devil and Buffalo cricket.

103. ANOPLODUSA ARIZONENSIS (Rehn) 1904 (*Drymadusa*).

CLARK COUNTY (*Bird Spring Mountains* (foothills) 11(VIII)07. –R & H) (Rehn and Hebard 1909).

Rehn and Hebards' comment (1909) is: "On August 11, while crossing the volcanic flats overgrown with greasewood at the foot of the Bird Spring Mountains of the McCollough range, on the Nevada side of the California boundary line, a specimen of this very rare species was flushed from a greasewood bush. It flew up in a way reminding one of the swift flight of a *Schistocerca* and did not alight for at least two hundred yards, when it perched on the top of another greasewood bush. The specimen was captured and proved to be the first known female of the genus." I have not seen it.

104. EREMOPEDES BILINEATUS (Thomas) 1875.

Listed by Ball et al. (1942) for "Nevada." I do not have it.

105. ATELOPLUS LUTEUS Caudell 1907.

MINERAL COUNTY (*Walker Lake* 14(VIII)38, el. 4050 ft. –E. R. & G. E. Tinkham) (Tinkham 1944). I have no specimens.

106. IDIOSTATUS ELEGANS Caudell 1907.

WASHOE COUNTY (*Peavine Mountain* (near Reno) 9(VI)40, el. 5000 ft. –LaR & Mahoney).

This large, tan species is quite similar superficially to *Anabrus,* but of somewhat smaller and slimmer appearance. I have it only from a sagebrush flat near Reno, where it was found one summer concentrated in large numbers in a quarter-acre thickly over-grown with wild sunflower (*Helianthus*) upon which they were feeding. Subsequently they were found feeding on *Artemisia tridentata* and *Bromus tectorum.* Generally, the species is not so gregarious and is usually found scattered thinly over its range. It has never been reported as of economic importance, although its habits suggest such a possibility under optimum breeding and growing conditions. The type comes from "Nevada (E. H. Hillman)" (Caudell 1907) and is very probably Reno material, since Hillman collected most of his specimens in and about Reno.

107. IDIOSTATUS INERMIS (Scudder) 1899 (*Cacopteris*).

WASHOE COUNTY (*Lawton* (*Dry Lake*) *Valley* (Cold Springs) 11(VII)36, el. 4500 ft. –LaR & Christensen; *Reno* (Truckee Meadows) 6(V)40, 9(VI)40, 9(VIII)40, el. 4500 ft. –LaR; *Washoe Valley* 6(VI)40, el. 4500 ft. –LaR & Mahoney).

This species is much smaller than *I. elegans,* and has been reported as causing some damage to crops in Washoe Valley, where I have seen small bands of crickets migrating westward across the valley into meadowland; resembling, on the march, similar bands of the larger and more destructive Mormon cricket. About Reno, the population has been found more thinly scattered, and no such migrating bands have been observed. Caudell (1907) knew it from Reno, probably from Hillman's collecting. The type came from the vicinity "of Lake Tahoe, Nevada, Sept., H. W. Henshaw, Lt. Wheeler's exploration of 1876" (Scudder 1899). I have a record of this species being parasitized by the sphecid wasp *Chlorion ichneumonium* at Reno, 2(VIII)41.

108. IDIOSTATUS NEVADENSIS (Scudder) 1899 (*Cacopteris*).

DOUGLAS COUNTY (*Gardnerville* 1(VIII)31, el. 4500 ft. –E. R. & H. A. Tinkham) (Tinkham 1944); EUREKA COUNTY (*Beowawe Hot Spring* 25(VI)41, el. 4700 ft. –LaR & Christensen); STOREY COUNTY (*Virginia City* 28–31(VII)31, el. 6500 ft. –E. R. & H. A. Tinkham) (Tinkham 1944).

In his original description, Scudder listed "Ruby Valley, Nevada, Ridgway; mountains near Lake Tahoe, Nevada, Oct. 14, Henshaw; Lt. Wheeler's explorations of 1876."

(IDIOSTATUS CALLIMERA Rehn & Hebard 1920.

Tinkham (1944) stated in error that this species was described from Nevada. Recourse to Rehn and Hebards' original description shows the type to have come from Inyo County, California, with another single specimen listed by them from the Whitney Pass Trail, California. I have been unable to find any published records for Nevada).

109. STEIROXYS PALLIDIPALPUS (Thomas) 1872.

Caudell (1907) recorded this species from "Ruby Valley, Nevada (Ridgway)." Scudder had previously (1894B) mentioned "Nevada" for the species, referring to Ridgway's specimens. I have not seen the species.

Subfamliy COPIPHORINAE

110. NEOCONOCEPHALUS TRIOPS (Linné) 1758 (also *Conocephaloides*).

CLARK COUNTY (*Logandale* 28(II)42, el. 4400 ft. –Mary Ellen Lyman).

Mrs. Marguerite E. Lyman, whose daughter collected the specimen, informs me the species is common in the vicinity of Logandale during summer, but overwintering individuals are rare. *N. triops* is common to the area south of Nevada, and in the West, at least, seems restricted to Creosote Zone.

Subfamily CONOCEPHALINAE

111. CONOCEPHALUS FASCIATUS VICINUS (Morse) 1901 (*Xiphidium, Xiphidion, Anisoptera*).

LYON COUNTY (*Wabuska* 5(IX)10, el. 4344 ft. –R & H); WASHOE COUNTY (*Reno* (Truckee Meadows) 2(IX)10, el. 4500 ft. –R & H (Rehn and Hebard 1915); 9–18(VII)40, –LaR; *Verdi* 29(VI)40, el. 4750 ft. –LaR; *Wadsworth Slough* 20(IX)41, el. 4000 ft. –LaR & Trelease).

A very common little green grass species. In 1880, Scudder recorded it from "Glen Brook and Reno, Nev." as *Xiphidium ensiferum* Scudder 1862, with the notation: ". . . agree with the ordinary type, excepting in the length of the wings which surpass the tip of the tegmina."

Family GRYLLACRIDIDAE

SUBFAMILIES OF GRYLLACRIDIDAE KNOWN TO OCCUR IN NEVADA

Hind femoral inserting angle situated on the outer side; antennal bases widely separated; fastigium plane, convex or shallowly-excavate—if the latter, occiput furnished with a percurrent median carina; tarsi with pulvilli .....Stenopelmatinae

Hind femoral inserting angle situated on the inner side; antennal bases subcontiguous; fastigium distinctly sulcate, or at least strongly compressed between the close-set antennal bases—occiput never with a median carina; metatarsi without true pulvilli or with a single distal pulvillus (some *Daihiniini* have pseudopulvilli formed by expanded ventral surfaces of coalesced hind tarsi.. .... Rhaphidophorinae

Subfamily STENOPELMATINAE

112. STENOPELMATUS FUSCUS Haldeman 1852 (*S. cephalotes* Walker 1869, *S. fasciatus* Thomas 1872, *S. oculatus* Scudder 1876, *S. longispinus* Brunner 1888, *S. irregularis* Brunner 1888, *S. hydrocephalus* Brunner 1888, *S. californicus* Brunner 1888, *S. comanchus* Saussure & Pictet 1897, *S. terrenus* Rehn 1902).

HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 18(VI)41, el. 4800 ft. –LaR & Christensen); WASHOE COUNTY (*Reno* (Truckee Meadows) 3(VII)38,

4(VIII)39, 6(IX)40, 8(VIII)41, el. 4500 ft. –LaR; *Twenty-mile House* (between Reno and Pyramid Lake) 28(IX)40, el. 5000 ft. –LaR, Trelease & Christensen); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 14(VIII)39, el. 7200 ft. –T. O. Thatcher; *Preston* (X)41, el 5000 ft. –5000 ft. U. N. Lanham).

A common sagebrush species, known under a variety of names, and occasionally reported as doing minor garden damage. Thomas (1875) listed *S. fasciatus* for "Nevada." Scudder (1899A) recorded *S. oculatus* from "Nevada, Akhurst, Edwards; Virginia City, Nev., Seckels; Carson Valley, Nev., Simpson; Ruby Valley, Nev., Ridgway," and was not sure it was distinct from *S. fasciatus*. At the same time he listed *S. irregularis* from "Lake Tahoe, Nevada, Sept., Henshaw." Hebard (1916) had a female *S. fuscus* from "Reno, Nevada." Davis and Smith (1926) came to the conclusion that *fuscus* and *longispinus*, which latter name had long stood as a species in the literature, were untenable as separate entities. Hebard (1928) disagreed with their conclusions, and felt there was a valid species under the name of *longispinus*. My present knowledge of the genus, based on a survey of approximately 300 specimens from localities representing widely-separated populations over the intermontane West, leads me to concur with Davis and Smith. If *fuscus* and *longispinus* are distinct, external morphology does not demonstrate the fact sufficiently well to separate them; the fleshy genitalia seem to offer little hope of clarifying the matter, but have not yet been adequately investigated.

S. fuscus is subterranean and largely nocturnal; it is not uncommon to find individuals wandering about the desert on cloudy days or late afternoons, but only when humidity is relatively high and the day cool. The species is omnivorous. The low distribution potential of this fossorial, ambulatorial animal would be conducive to the relatively rapid segregation of biotypes in the topographically-disturbed montane West in the course of time. It is possible *fuscus* stock has not been in the area long enough to produce regional stability from various elements of its biotic potential—a survey of even a limited number of specimens of *S. fuscus* immediately demonstrates the wide variation potential of the species; such facts lead one to believe the species has only recently expanded through the higher, broken land between the Rocky Mountains and the Sierra Nevadas.

Subfamily RHAPHIDOPHORINAE

GENERA OF RHAPIDOPHORINAE KNOWN, OR LIKELY TO OCCUR, IN NEVADA
(adapted from Hubbell 1936)

1. First segment of hind tarsi apically spinose above; hind tibiae above lacking moveable spines except apically; fastigium biconical 2
—First segment of hind tarsi not apically-spinose above; hind tibiae above with moveable spines (interspersed with fixed spines) extending above the apical area; fastigium conical, occasionally with faint trace of a sulcus 3
2. Femora rounded above; first segment of hind tarsi alone spinose above apically; fore and middle legs unarmed except at tibial apex; dorsal and ventral ovipositor valves armed with stout teeth (Pacific Coast) ..... (*Gammarotettix*)
—Femora bicarinate above; first two segments of hind tarsi apically spinose above; all tibiae square in section, armed on all four angles with a long series of sharp, overlapping spines; dorsal ovipositor valves unarmed, ventral valves with apices crenulate (Pacific Coast) ..... (*Tropidischia*)

3. ♂ ♂ styles present; ventral ovipositor valves armed distad with crenulations or numerous low serrations; tarsal claws with a distinct sensory seta ventroproximally ..... *Pristoceuthophilus*
—♂ ♂ styles absent; ventral ovipositor valves armed with 4-8, usually 5, triangular or acicular teeth (including the decurved hook-like apex as one), these rarely serratiform or subobsolete; tarsal claws without such sensory setae 4

4. All tarsi 4-segmented; elevated margins of antennal fossae with bases attingent or nearly so medially 5
—Fore, or fore and hind tarsi 3-segmented; elevated margins of antennal fossae with bases separated by a space at least as broad as middle breadth of antennae 6

5. Dorsal spurs of hind tibia crowded apically, interval between two apical spurs not or very slightly greater than breadth of one of them; hind tarsal claws at least as long as last tarsal segment (California) ..... (*Rhachocnemis*)
—Dorsal spurs of hind tibiae widely-separated, or if somewhat crowded apically then interval between two apical spurs at least twice, generally much more than twice, the breadth of one of them; hind tarsal claws usually shorter than last tarsal segment ..... *Ceuthophilus*

6. Fore and hind tarsi 3-segmented, the composite nature of proximal segment often indicated by a notch in the ventral keel ..... *Ammobaenetes*
—Fore tarsi alone 3-segmented ..... (*Daihiniodes*)

113. CEUTHOPHILUS ARIZONENSIS Scudder 1894.

EUREKA COUNTY (*Devil's Gate* 1(IX)24, el. 6950 ft. –R & H); LANDER COUNTY (*Big Creek Cañon* (Toyabe Range) 3(IX)24, el. 6000 ft. –R & H) (Hubbell 1936).

Hubbell expressed doubt as to the identifications. I have no specimens.

114. CEUTHOPHILUS UNGUICULATUS Hubbell 1936.

HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 18(VI)41, el. 4800 ft. –LaR & Christensen).

Specimens were obtained by molasses-baiting sunken jars in the sand, but were not common. Usually such traps were found filled in the morning with examples of the large, lumbering tenebrionid *Eleodes obscura sulcipennis* and its smaller counterpart, *E. hispilabris imitabilis*, both of which wandered at night about the dunes in large numbers.

115. CEUTHOPHILUS CAUDELLI Hubbell 1936 (*C. perplexus* Hubbell 1936).

HUMBOLDT COUNTY (*Paradise-National Summit* (Santa Rosa Mountains) 22(VI)41, el. 7600 ft. –LaR & Chtristensen); LINCOLN COUNTY (*Hiko* 1(I)41, el. 3800 ft. –LaR); WASHOE COUNTY (*Peavine Mountain* (near Reno) 8(II)39, 4(VI)39, 11(V)46, el. 6000 ft. –LaR).

In the mountains about Reno, this variable species is common under rotten logs and in rodent burrows. Some individuals agree well with the description of *C. caudelli*, others with that of *C. perplexus*, and intergrading forms are common, so it seems best to consider the latter name as part of the synonymy of *caudelli*. About Reno, its preferred habitat is the Jeffrey pine timber (*Pinus ponderosa jeffreyi*). At the Santa Rosa Mountains locality, large series were taken by molasses-baiting burrows of the gopher *Thomomys talpoides* in a high, open meadow.

116. CEUTHOPHILUS HEBARDI Hubbell 1936.

CLARK COUNTY (*Spring* (*Charleston*) *Mountains* (Charleston Peak) 14(VIII)31, el. 11,400 ft. –E. R. Tinkham; (*Lee Cañon*) 19(VIII)19, el. 9000 ft. –Hebard) (Hubbell 1936); ELKO COUNTY (*Lamoille Cañon* (Ruby Mountains) 26(VI)41, el. 7000 ft. –LaR & Christensen); NYE COUNTY (*Cactus Spring* (Cactus Range) 25(VIII)24, el. 6400 ft. –R & H) (Hubbell 1936); WASHOE COUNTY (*The Spaniard's* (Virginia Range, near Reno) 26(II)41, el. 5000 ft. –LaR, Trelease & Christensen).

Hubbell was dubious of the identity of the two juvenile specimens representing the Nye County locality. In his description of *C. vinculatus* in 1894, Scudder listed "Nevada, H. Edwards," as well as specimens from other States. Hubbell submerges the name into the synonymicon of *C. alpinus* Scudder 1894, which seems to be pre-eminently a Rocky Mountain species, and expresses the opinion it is more likely the Nevada record applies to *C. hebardi.*

117. CEUTHOPHILUS FOSSOR Hubbell 1936.

HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 18(VI)41, el. 4800 ft. –LaR & Christensen); NYE COUNTY (*Toyabe Range* 2(VI)15, –E. G. Holt) (Hubbell 1936); PERSHING COUNTY (*Nightingale Mountains* (Old Mill on west side) 22(VII)46, el. 4100 ft. –LaR); WASHOE COUNTY (near *Gerlach* 2(VII)41 el. 3950 ft. –LaR & Christensen; *North Pyramid Lake dunes* 20(VI)46, el. 3850 ft. –LaR & Christensen; *South Pyramid Lake dunes* 18(VI)46, el. 3850 ft. –LaR & Christensen).

Originally described from Arizona, and also known from southern California, the above records constitute considerable northward extensions of the species' range. *C. fossor* is the common camel cricket of the Nevada desert, abundant in rodent burrows, and usually readily taken wandering about at night in sanded areas. On sand dunes, where they are common, a coleman lamp placed beside a bush will usually, in season, bring one to several *fossor* out to investigate. Ball et al. (1942) lists "Nevada" as part of the range.

(CEUTHOPHILUS UTAHENSIS Thomas 1876.

Records (Hubbell 1936) from extreme southwestern Utah and southern Idaho are immediately adjacent to Nevada where similar habitats exist which are continuous with those from which *utahensis* is already known).

(CEUTHOPHILUS HUALAPAI Hubbell 1936.

A species of northwestern Arizona adjacent to extreme southern Nevada).

(CEUTHOPHILUS INYO Hubbell 1936.

A high Sierran species which is to be looked for in the vicinity of the Nevada side of Lake Tahoe, where the Sierras intrude farthest into the State).

118. PRISTOCEUTHOPHILUS PACIFICUS (Thomas) 1872.

DOUGLAS COUNTY (*Glenbrook* (Lake Tahoe) 12(VI)40, el. 6300 ft. –LaR & Lowrance)

Scudder (1894) reported this from the "mountains about Lake Tahoe, Cal., Oct., H. W. Henshaw, in Capt. Wheeler's Expl., 1876," adjacent to the Nevada line.

119. AMMOBAENETES LARIVERSI Strohecker 1944.

CHURCHILL COUNTY (*Sand Spring dune* 5(VII)41, el. 4500 ft. –LaR & Christensen; 29(VII)46, –LaR); LYON COUNTY (near *Mason* 28(VIII)46, el. 5600 ft. –LaR); PERSHING COUNTY (*Nightingale Mountains* (Old Mill on west side) 22(VII)46, el. 4100 ft. –LaR); WASHOE COUNTY (*South Pyramid Lake dunes* 18(VI)46, el. 3850 ft. –LaR & Christensen).

This is a distinctive little animal, living in burrows in the more solid sands on the lower portion of the type locality, a large aeolian dune at Sand Spring; nocturnal, they begin coming from their burrows during the last minutes of crepuscularity, at which time they can be found sitting in the tunnel entrances. When darkness reaches totality, they leave the burrows and feed among surrounding vegetation. If the animal is prevented from returning to its burrow, it quickly digs itself into the sand with the strong, spinous hind tibiae so admirably adapted for such work. The species is one of the commonest animals at the dune, and has been found in only three other areas, all heavily sanded. The Pyramid Lake locality, where the species is abundant, was under lake waters 30 years ago. Like the recently-described dune tenebrionid *Lariversius tibialis*, this species is known only from arenaceous areas along or within the extensive shorelines of extinct Pleistocene Lake Lahontan, which, if nothing else, seems to have been responsible for the vast extensions of sand which now dot many portions of its old basin and provide optimum habitats for several distinctive arenaceous species which exist upon them at the present time with what appear to be maximum population densities.

At Pyramid Lake, *Ammobaenetes* was found with *Ceuthophilus fossor*, both wandering widely over the dunes and sanded *Atriplico-Sarcobatetum* at night. The Mason locality was a very small duned spot about a once-massive copper mill and mine in the hills over 1000 feet above the valley floor—the spot is completely isolated from all other arenaceous areas. The species was common, but no *Ceuthophili* were found, although the usual dune tenebrionids were present.

That the food of *Ammobaenetes* may be quite variable is shown by information supplied by Thomas J. Trelease of Sparks and Glen C. Christensen of Reno that they found the species feeding on dried hulks of the dune tenebrionid *Eusattus muricatus* (*Sphaeriontis*) on the Sand Spring dune. In this locality, I found the common scorpion, *Vejovis boreus*, preying upon the cricket, while a large desert Hairy scorpion, *Hadrurus hirsutus*, was taken at the Nightingale Mountains locality feeding on an adult *Ammobaenetes*.

Family ACHETIDAE (Gryllidae)

SUBFAMILIES OF ACHETIDAE KNOWN TO OCCUR IN NEVADA

1. Hind tibiae unarmed except apically ..... Mogoplistinae
—Hind tibiae armed with two series of spines 2
2. Wingless; hind femora ovate, very markedly swollen ..... Myrmecophilinae
—Winged; hind femora not as above, much slenderer 3
3. Hind tibiae with minute teeth between the spines ..... Oecanthinae
—Hind tibiae lacking such teeth ..... Achetinae

Subfamily MOGOPLISTINAE

120. CYCLOPTILUM COMPREHENDENS Hebard 1929.

CLARK COUNTY (*Porter's Well* (Dead or Newberry Mountains) 17(V)37, el. 800 ft. –LaR & Hancock).

A Creosote Zone species confined to the southern part of the State.

Subfamily ACHETINAE (Gryllinae)

THE GENERA (AND SPECIES) OF ACHETINAE KNOWN TO OCCUR IN NEVADA

1. Hind tibial spines long, movable, pilose; last maxillary palpal segment at least twice as long as the preceding segment; basal hind tarsal segment unarmed above ..... *Nemobius cubensis mormonius*
—Hind tibial spines stout, immovable; last maxillary palpal segment not more than 1/3 longer than preceding segment; basal hind tarsal segment serrate above on both margins 2
2. Hind tibiae ¾ or more the length of hind femora, armed with 5-8 spines on each margin ..... *Acheta assimilis*
—Hind tibiae not more than 2/3 the length of hind femora, armed above with 4-5 spines on each margin ..... *Miogryllus lineatus*

121. ACHETA ASSIMILIS Fabricius 1775 (*Gryllus, Gryllulus*).

HUMBOLDT COUNTY (*Paradise-National Summit* (Santa Rosa Mountains) 22(VI)41, el. 7600 ft. –LaR & Christensen); MINERAL COUNTY (*Walker Lake* (south end) 7(VII)41, el. 4050 ft. –LaR & Christensen); PERSHING COUNTY (*Lovelock* 15(VI)41, el. 4200 ft. –LaR & Christensen; *Nightingale Mountains* (Old Mill on west side) 22(VII)46, el. 4100 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 25(V)41, el. 4500 ft. –LaR).

The common cricket, occurring throughout the State, and exhibiting considerable variation in size and color, so much so that its synonymicon now contains in excess of 45 names (Hebard 1929). At the Walker Lake locality, *A. assimilis* fed on the common grasses and weeds during the day, and was prey to the carabid *Calosoma parvicollis* at night.

122. MIOGRYLLUS LINEATUS (Scudder) 1876 (*Gryllodes*).

CLARK COUNTY (*Gypsum Cave* 29(X)40, el. 1700 ft. –LaR; *Las Vegas* 9(VIII)07, el. 2028 ft. –Hebard; 2(IX)09, –R & H) (Hebard 1915).

This small Creosote Zone species has so far been taken only in extreme southern Nevada. In my experience, it inhabits the driest hillsides, and is often the only insect to be readily found in such situations. Rehn and Hebards' 1909 notation is: "Two males of this species were taken at Las Vegas, Nevada, August 9, on an ore pile, where a colony of these were chirping incessantly. The type of the species was taken between Virgin River and Fort Mohave, Arizona."

123. NEMOBIUS CUBENSIS MORMONIUS Scudder 1896.

CLARK COUNTY (*Las Vegas* 10(VIII)07, el. 2028 ft. –R & H) (Rehn and Hebard 1909).

Ball et al. (1942) repeat the Nevada record. I have no specimens.

Subfamily OECANTHINAE

124. OECANTHUS NIVEUS (DeGeer) 1773 (*OE. rileyi* Baker 1905).

HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 31(VII)46, el. 4800 ft. –LaR); LINCOLN COUNTY (*Hiko* 10(X)40, el. 3800 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 10(VIII)40, 31(VIII)41, el. 4500 ft. –LaR; *Verdi* 6(VIII)40, el. 4750 ft. –LaR).

A common species, found in both sagebrush (*Artemisia tridentata*) and willow (*Salix*) groves along river bottoms, often in considerable numbers. Extremely shy and difficult to approach when singing in the daytime, but seemingly indifferent to the light of a coleman lamp at night and then easily found. I have them from all the common trees and shrubs in the vicinity of Reno. In certain desert areas where the introduced weed *Salsola kali tenuifolia* (Russian thistle) remains green and succulent after native grasses and annuals have dried up, *OE. niveus* often swarms on the plants at night.

125. OECANTHUS CALIFORNICUS Saussure 1874.

WASHOE COUNTY (*Reno* (Truckee Meadows) 28(VII)40, el. 4500 ft. –LaR).

126. OECANTHUS NIGRICORNIS QUADRIPUNCTATUS Beutenmeuller 1894.

WASHOE COUNTY (*Reno* (Truckee Meadows) 28(VII)40, el. 4500 ft. –LaR).

—OECANTHUS NIGRICORNIS ARGENTINUS Saussure 1874 (*OE. rehni* Baker 1905).

CHURCHILL COUNTY (*Fallon* 28(IX)40, el. 4000 ft. –LaR; *Rawhide Sands* 28(VIII)46, el. 4200 ft. –LaR).

The *OEcanthi* are a prominent part of the State's orthopterous fauna, and in most localities with which I am familiar, can be credited with, often, at least 70% of all sounds of orthopterous origin; size-for-size, there are perhaps no more vigorous noise-makers among the arthropods. At the Rawhide locality, this variety was common on the still-green *Salsola kali tenuifolia*, associated with the large *Plagiostira gillettei*, *Melanoplus complanatipes* and *M. packardi*.

Tinkham (1938) records specimens of *OEcanthi* coming to light at night. My experience with them in the desert has left me impressed with their indifference to light.

Subfamily MYRMECOPHILINAE

127. MYRMECOPHILA OREGONENSIS Bruner 1884.

DOUGLAS COUNTY (near *Zephyr Cove* (Lake Tahoe) 10(X)41, el. 6400 ft. –LaR).

Hebard (1920A) reported the species from Lake Tahoe, California.

128. MYRMECOPHILA MANNI Schimmer 1911.

WASHOE COUNTY (*Reno* (Truckee Meadows) 21(VI)36, el. 4500 ft. –LaR).

Hebard (1920A) listed it from Pyramid Lake (Washoe County), taken in nests of the ants *Myrmica mutica* Emery and *Formica neogagates vetula* Wheeler.

Suborder BLATTODEA
Superfamily BLATTOIDEA
Family BLATTIDAE

SUBFAMILIES OF BLATTIDAE KNOWN TO OCCUR IN NEVADA

1. Middle and hind femora armed below only with apical or subapical spines 2
—Middle and hind femora armed below along one or both margins with distinct spines 3
2. Winged; delicate, slender, light-greenish species; adventive .....Panchlorinae
—Wingless; robust, ovate, light-brownish species; native .....Polyphaginae
3. Large, robust and heavily-chitinized, pronotum more than 7 mm. long .....Blattinae
—Small, delicate, pronotum less than 7 mm. long .....Pseudomopinae

Subfamily PSEUDOMOPINAE

THE GENERA (AND SPECIES) OF PSEUDOMOPINAE KNOWN TO OCCUR IN NEVADA

Ventro-cephalic margin of fore femora armed with a row of heavy proximal spines, succeeded by a row of more slender, shorter, apical spines; field species ..... *Parcoblatta americana*

Ventro-cephalic margin of fore femora armed with a row of spines which decrease gradually in size and length apically; household pest .....*Blattella germanica*

129. BLATELLA GERMANICA (Linné) 1767.

WASHOE COUNTY (*Reno* (Truckee Meadows) 16(VIII)38, el. 4500 ft. –LaR); WHITE PINE COUNTY (*Ely* 20(IX)39, el. 6470 ft. –LaR).

A cosmopolitan species well-established throughout the State.

130. PARCOBLATTA AMERICANA (Scudder) 1900 (*Loboptera*).

DOUGLAS COUNTY (near *Zephyr Cove* (Lake Tahoe) 8(VII)41, el. 6300 ft. –Trelease); WASHOE COUNTY (*Reno* (Truckee Meadows) 16(VII)36, el. 4500 ft. –LaR).

A common, innocuous field species readily taken under stones, logs, etc.

Subfamily BLATTINAE

131. PERIPLANETA AMERICANA (Linné) 1758.

CHURCHILL COUNTY (*Fallon* 9(IX)39, el. 4000 ft. –LaR); ELKO COUNTY (*Elko* 8(VII)39, el. 5000 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 6(VI)35, 1(XII)39, 8(III)41, el. 4500 ft. –LaR).

A very common domestic pest, the largest of the family in Nevada.

Subfamily PANCHLORINAE

132. PANCHLORA MINOR Saussure & Zehntner 1893.

WASHOE COUNTY (*Reno* (Truckee Meadows) 15(VI)40, el. 4500 ft. –LaR).

I have but a single specimen of this tropical species from an alfalfa field near Reno; this is not the first instance of its appearance in the State, and it seems to be a common adventive on produce of tropical origin entering the United States.

Subfamily POLYHAGINAE (Corydinae)

133. ARENIVAGA ERRATICA (Rehn) 1903 (*Homoeogamia*).

CLARK COUNTY (*Las Vegas* 29(X)40, el. 2250 ft. –LaR); WASHOE COUNTY (*Wadsworth Slough* 14(IX)41, el. 4000 ft. –LaR & Trelease).

To my knowledge, this is the first record of the species for Nevada, although it has been taken in adjacent California, Arizona and Utah. Wherever I have collected it, it has been common, and seems primarily a desert species, occurring in large numbers occasionally along desert streams.

134. ARENIVAGA APACHA (Saussure) 1893 (*Homoeogamia*).

CLARK COUNTY (*Stump Springs* (Pahrump Valley) 1(VI)37, el. 2100 ft. –LaR & Hancock).

This also seems a new State record, although the species has previously been collected in California near the Nevada line.

Suborder PHASMODEA

Superfamily PHASMOIDEA

Family PHASMIDAE (Bacunculidae)

SUBFAMILIES OF PHASMIDAE KNOWN TO OCCUR IN NEVADA

Antennae shorter than fore femora ..... Pachymorphinae
Antennae longer than fore femora ..... Heteronemiinae

Subfamily PACHYMORPHINAE

135. PARABACILLUS HESPERUS Hebard 1934.

CLARK COUNTY (*Lee Cañon* (Spring or Charleston Mountains) 18–22(VIII)19, el. 4000 ft. –R & H); LINCOLN COUNTY (*Caliente* 3(IX)09, el. 5200 ft. –R & H) (Hebard 1934B); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 3(IX)37, el. 8000 ft. –T. O. Thatcher). I have no specimens.

Described from the Pajaritos Mountains of Arizona from 5500-6100 feet elevations. Rehn and Hebard's specimens were found (Caliente) "in dry grasses on mountain side" and (Lee Cañon) "in tufts of slender yellow grass, zone of Tree Yucca" (Hebard 1934B). Hebard further commented that "The present insect is known north to the Wah Wah Range, Utah; Caliente, Nevada, and the Steens Mountains and Boardman, Oregon; west to the Pacific (but absent over most of the area west of the Sierras); south to the Mexican boundary, and east to the Huachuca Mountains, Arizona, and Leeds and Bellevue, Utah."

Subfamily HETERONEMIINAE

THE GENERA (AND SPECIES) OF HETERONEMIINAE KNOWN TO OCCUR IN NEVADA

Hind femora armed ventrad with a spine near apex; ♂ ♂ middle femora markedly enlarged ..... *Diapheromera arizonensis*
Hind femora unarmed beneath near apex; ♂ ♂ middle femora slender ..... *Pseudosermyle straminea*

136. DIAPHEROMERA ARIZONENSIS Caudell 1903.

CLARK COUNTY (*Muddy Mountains* (south end) 11(VI)37, el. 3000 ft. –LaR & Hancock).

Camp was made in a dry wash, and this specimen was discovered walking sedately through the lamp-lit wash at night, seemingly attracted by the coleman lamp.

137. PSEUDOSERMYLE STRAMINEA (Scudder) 1902 (*P. truncata* Caudell 1903, *P. tenuis* Rehn & Hebard 1909; *Bacunculus*).

CLARK COUNTY (*Keystone Cañon* (Spring or Charleston Mountains) ((VI)37, el. 4800 ft. LaR & Hancock; WHITE PINE COUNTY (*Lehman Caves National Monument* near Baker) 25(VIII)37, 16–19(IX)39, el. 8000 ft. –T. O. Thatcher).

The phasmode population of Nevada is hardly known, and none of the species seem common.

Suborder MANTEODEA

Superfamily MANTEOIDEA

Family MANTEIDAE (Mantidae)

SUBFAMILIES OF MANTEIDAE KNOWN TO OCCUR IN NEVADA

Hind femora armed exteriorly with an apical spine; pronotum only slightly longer than fore coxae; small, less than 1½ inches long ..... Ameliinae
Hind femora unarmed as above; pronotum much longer than fore coxae; large, more than 2 inches long ..... Manteinae

Subfamily AMELIINAE

138. LITANEUTRIA MINOR (Scudder) 1872 (*L. ocularis* Saussure 1892, *L. obscura* Scudder 1896, *L. pacifica* Scudder 1896, *L. skinneri* Rehn 1907, *L. longipennis* Beier 1929; *Stagmatoptera*).

CLARK COUNTY (*Porter's Well* (Dead or Newberry Mts.) 17(V)37, el. 800 ft. –LaR & Hancock); HUMBOLDT COUNTY (*Paradise Valley dunes* (near Winnemucca) 31(VII)46, el. 4800 ft. –LaR); WASHOE COUNTY (*Reno* (Truckee Meadows) 16(VII)38, el. 4500 ft. –LaR); WHITE PINE COUNTY (*Lehman Caves National Monument* (near Baker) 8(VIII)38, el. 8000 ft.; 14(IX)40, el. 4500 ft. –T. O. Thatcher).

A very common species in the *Artemisietum* and *Larreetum* throughout the State, and often attracted to lights at night.

Subfamily MANTEINAE (Mantinae)

139. STAGMOMANTIS LIMBATA (Hahn) 1835.

LINCOLN COUNTY (*Hiko* 12(VIII) 40, el. 3800 ft. –LaR).

The northernmost record known to me.

140. STAGMOMANTIS CALIFORNICA Rehn & Hebard 1909.

CHURCHILL COUNTY (*Rawhide Sands* 28(VIII)46, el. 4200 ft. –LaR); CLARK COUNTY (*Las Vegas* 29(X)40, el. 2250 ft. –LaR).

At the Rawhide locality, the solitary specimen obtained flew to the coleman lamp at night.

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A Noteworthy Molluscan Faunule from Northeastern Washington

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In the course of a brief stay at Northport, Washington, in June of 1929, Mr. Etval J. Newcomer of Yakima collected samples of lacustrine deposit there which proved to be so full of molluscan remains that he forwarded them to the present writer for examination. The material was duly worked over and a short MS upon it prepared for publication. Submission to the printer was none the less delayed in the hope of securing the opinion of a competent specialist regarding the representatives present of that most difficult family, the Physidae. Since at this advanced date we seem no nearer to attainment of the desired information, and the remainder of the material possesses far too great intrinsic interest to justify our keeping it longer buried, the old notes have been exhumed, and are here offered after extensive revision and emendation which more recent extensions of knowledge in the field have made possible.

Description of Site

The site whence these samples were obtained is the former bed of a small pond about two miles southeast of Northport, Washington, which was drained, according to my information, nearly fifty years ago in order that the land might be reclaimed for farming. Subsequently to Mr. Newcomer's visit, Dr. M. C. Goldsworthy collected and forwarded additional material in which was represented most of the species found in the first sample and in addition to these one or two others not previously encountered. Dr. Goldsworthy wrote (in *litt.*) "I tried to go up as far as possible on the sides of the old lake, and the samples marked shore line are from such locations, while those marked lake bottom are from the rich material in the central portion of the old lake bed. Up further along the sides the soil is quite calcareous but one cannot find the tiny shells there."

Character of Material

The character and composition of the respective samples varied, according to the position in the old lake bed whence they were taken, from a brownish black fibrous peaty deposit to a gray clay-marl, some bits of which were quite solid and friable only with difficulty. The molluscan remains present included mainly fluviatile or rather lacustrine forms, but there are some half dozen terrestrial species represented, and of these one, *Vertigo ovata*, appeared in considerable abundance. A few of the terrestrial specimens, especially some of those from the most peaty samples, are quite fresh in appearance and evidently represent species now living on the surface of the deposit or on the slopes immediately surrounding it, rather than true constituent forms. In contrast,

practically all the fresh-water shells are now whitish and more or less chalky and friable.

The various samples of substrate differ not only in physical composition but in some respects in organismic content as well. For instance most of the more minute lymnaeids were extracted from the most peaty sample. On the other extreme one sample of almost pure clay from the southwest side near the former shore-line yielded hardly any mollusks at all, only the following being recovered: 1 *Pisidium* sp., 1 *Gyraulus altissimus* (Baker), and 3 *Valvata humeralis californica* Pilsbry.

Another small sample taken near the margin of the pond in another location yielded a disproportionate representation of the various terrestrial species (nearly one-half the specimens) and included three species (*Pisidium roseum, Allogona ptycophora, Gastrocopta pentodon*) not detected elsewhere in the deposit together with the single living *Succinea*, to wit: 2 3/2 *Pisidium roseum* Sholtz, 4 *Helisoma subcrenatum* (Carpenter), 3 *Gyraulus altissimus* (Baker), 1 *Allogona ptycophora* (W. G. Binney), 3 *Zonitoides arboreus* (Say), 1 *Gastrocopta pentodon* (Say), 1 *Succinea* cf. *hawkinsii* Baird, living.

It is sufficient to the purpose to cite one further small sample from the east side ("near alluvial soil"), which yielded: 3 *Pisidium* cf. *concinnulum* Sterki, 2 *Pisidium rotundatum* Prime, 1 *Lymnaea* (*Fossaria*) *dalli* Baker, 4 *Gyraulus altissimus* (Baker), 6 *Menetus exacuous megas* (Dall), 39 *Valvata*

Fig. 1.—Panoramic view of site of former pond [illegible] of No

humeralis californica Pilsbry, 1 *Euconulus fulvus* (Müller), 1 *Zonitoides arboreus* (Say), 2 *Vertigo ovata* (Say).

PROBABLE AGE OF FAUNULE

It was thought, when the study was begun, that the molluscan remains were mere relicts of the now-drained pond and its immediate drainage basin. This may still be their true interpretation, but if so the list of species represented, so far as these of fresh-water habit are concerned, it is a most peculiar one and not closely paralleled by any other faunal list yet made known from the region—cf. the species and localities catalogued by Henderson (1929a, 1936). On the other hand several species appear to be identical with some which have hitherto appeared characteristic of deposits occurring in southern Canada and the central northern United States which are generally accepted as of late Pleistocene age, though here again it will be seen that in some essential particulars the assemblage is contrastingly different from those reported by Henderson (1928, 1929) from Pleistocene beds of the Grand Coulee region.

Since I have never seen the site in person it becomes quite impossible here to venture an opinion as to whether the bulk of the material may represent a period of deposition older than the historic lake. However, some of the species

r pond t of Northport; from photograph by D. F. Fisher.

concerned and the differences in preservation already noted between the freshwater shells and many of those of terrestrial origin are sufficient to suggest that such a possibility should be well and carefully considered in any final attempt to interpret the faunale, although I consider it very questionable, from the general character of the site as it has been described, that any of the material will prove to be of sufficiently ancient origin to be called Pleistocene.

In any event some extremely interesting distributional data have been brought to light and several important species added to the known fauna of the state of Washington and the Columbia Basin. The occurrence of *Pisidium concinnulum* (if verified), *P. roperi, P. rotundatum, Lymnaea dalli, Gyraulus altissimus, Armiger crista,* and *Gastrocopta pentodon* becomes especially noteworthy in this connection since in the literature available to me I have chanced upon no previous records of their occurrence in the area. The abundance of a form of *Menetus exacuous* in a locality so close to the metropolis of the *opercularis*-group is likewise worthy of mention.

ACKNOWLEDGMENTS

As the list of species is a fairly extensive one and accuracy of determination is so necessary for sound distributional conclusions, I have been to some pains to secure the cooperation of experienced specialists with some of the more difficult groups. I am particularly indebted for such aid to the late Dr. Victor Sterki (Sphaeriidae) and Dr. Frank Collins Baker (Lymnaeidae and Planorbidae), without whose kind assistance I should several times have found myself in a bad way. I am further indebted to Dr. M. C. Goldsworthy and Mr. D. F. Fisher of the United States Bureau of Plant Industry for prints of Mr. Fisher's fine photographs of the old lake bed and permission to publish them.

LIST OF SPECIES

A. LACUSTRINE

1. *Pisidium* cf. *concinnulum* Sterki—abundant.
2. *Pisidium roperi* Sterki—a few.
3. *Pisidium roseum* Sholtz—a few.
4. *Pisidium rotundatum* Prime—abundant.
5. *Musculium* cf. *secure* (Prime),—a few valves.
6. *Lymnaea* (*Stagnicola*) *proxima* Lea, var.—a few.
7. *Lymnaea* (*Fossaria*) *dalli* F. C. Baker—not uncommon.
8. *Helisoma subcrenatum* (Carpenter)—not uncommon.
9. *Gyraulus altissimus* (F. C. Baker)—abundant.
10. *Armiger crista* (Linné)—a few.
11. *Menetus exacuous megas* (Dall).
12. *Physa* sp.—common.
13. *Aplexa hypnorum* (Linné)—quite common.
14. *Valvata humeralis californica* Pilsbry—abundant.

B. TERRESTRIAL

15. *Allogona ptycophora* (W. G. Binney) one shell.
16. *Euconulus fulvus* (Müller)—common.
17. *Zonitoides arboreus* (Say)—a few.
18. *Discus* (*Gonyodiscus*) *cronkhitei* (Newcomb)—one shell.
19. *Vertigo ovata* (Say)—common.
20. *Gastrocopta pentodon* (Say)—one shell.
21. *Succinea* cf. *hawkinsii* Baird—not rare; one living example taken.

SUPPLEMENTARY NOTES ON THE SPECIES

4. *Pisidium rotundatum* Prime.—Baker (1929:311) records this species from the Early Wisconsin Pleistocene of Illinois; Baker and Cahn (1931:47) report it from Hamilton and Kimmewin Lakes, Ontario.

7. *Lymnaea dalli* F. C. Baker.—Baker (1930:427) describes a var. *grandis* from the Late Wisconsin Pleistocene in Illinois.

8. *Helisoma subcrenatum* (Carpenter).—This is the only fresh-water species of any size in the collection. Baker at first identified the shells with *H. caribaeum* (d'Orbigny), a determination which, on geographical grounds if no other, I thought open to strong challenge, but he later came around to the more reasonable conclusion here given.

9. *Gyraulus altissimus* F. C. Baker.—This small species, exceedingly abundant in the old lake deposit, was originally described (Baker 1919:95, pl. 7, figs. 7-10) as related to *deflectus* (Say), but with more sharply carinated upper whorls, the juvenile shells formed much like *Helisoma campanulatum*, and having other small peculiarities of structure. The type material was taken from post-glacial marl on the university campus at Urbana, Illinois. The species was later recorded by Baker as found from Early Yarmouth to Late Wisconsin in the Illinois Pleistocene, and as widespread in Late Wisconsin deposits of Illinois, Indiana, Wisconsin, Michigan, and apparently Minnesota (Baker 1929:307; 1930:431; 1935:260, 267, 272). According to Baker (1930: 431) as of this date "no true *altissimus* has been seen from the recent fauna." and Baker and Cahn (1931:60) add that it is "the only member of the family known from early and middle Pleistocene time." The latter authors consider *altissimus* to include the ancestral stock of both *G. circumstriatus* (Tryon) and *G. arcticus* (Beck). Shells reported some time later from Waskesiu Lake, Saskatchewan (Baker, 1937:116) are thought possibly to have been washed from a Pleistocene deposit, although by this date Baker appeared to feel much less certain that the species is today altogther extinct. The North port specimens were originally determined by Baker as his *G. urbanensis* (1919:94, pl. 7, figs. 4-6), which he described at the same times as *altissimus* and from the same post-glacial deposit, but which he subsequently conceded to the synonymy of *G. circumstriatus* (Tryon), contrasting its shell to that of the related *G. parvus* (Say) by its round apetture, descending body-whorl, deeper suture, and so on. Upon more extended study, however, he felt our shells to be better placed with *altissimus*. One can only agree with Baker and Cahn (1931:60) that "the small planorbes are very perplexing," although the uncertainty might partially resolve itself were we less ignorant of the anatomy of the various living species and races. A small *Gyraulus* which I have collected in the Lower Cretaceous of Montana does not appear to have been strikingly different from some of these living forms. It is a strangely conservative type.

10. *Armiger crista* (Linné).—This is one of the most interesting and unexpected forms taken, yet there seems little doubt of the correctness of the deter-

mination. The species is primarily Palaearctic in distribution, but Nearctic records are coming to light with increasing frequency, especially as more attention is paid to the study of marl deposits. It has been reported by Baker (1929:308; 1930:432) as occurring rarely in Illinois in deposits attributed to both Early and Late Wisconsin Pleistocene, and likewise (1935:272) in marl of presumably corresponding age in Minnesota. Baker (*op. cit.*) records this species as living in Little North Star Lake, Minnesota, while Whiteaves has recorded it from a lake N.E. of Carberry, Manitoba, and Red Deer, Alberta is an additional locality cited by Dall (1905:97).

11. *Menetus exacuous megas* (Dall).—This very striking race was first reported by Dall (1905:91) from Birtle, Manitoba, describing its shell as "of a slightly milky translucency; on the base the whorl is more or less impressed within the peripheral keel and the spiral striation is much more marked than in the typical form," while at the same time it is more than half again as large (7.8 mm. as against 4.7 mm. diameter). Baker (1930:430), to whom we owe most of our subsequent records, reports this variety, "known by the sharp, pinched nature of the peripheral keel," as occurring rarely in the Late Wisconsin Pleistocene of Illinois, but more commonly associated with the typical form in strata of corresponding age in Wisconsin, Michigan, and Ohio, though as yet undetected in earlier deposits. It is also reported from the (presumably) Late Wisconsin Pleistocene of Little North Star Lake, Minnesota (Baker, 1935; 267, 271), as well as living in Cat and Fitchie Lakes, Ontario (Baker and Cahn, 1931: 59), Little North Star Lake, Itasca Co., Minnesota (Baker, 1935: 271), and Crean Lake, Saskatchewan (Baker, 1937:116). The association at Northport of *M. e. megas, Gyraulus altissimus,* and *Armiger crista* thus appears altogether reasonable and harmonious.

13. *Aplexa hypnorum* (Linné).—This species is of widespread current distribution throughout our northern states.

14. *Valvata humeralis californica* Pilsbry.—At present I can identify the commonest mollusk by far in the Northport deposit only in this way, but the specimens are not typical, averaging notably smaller and I think rather more elevated than originals and other specimens in my collection from the San Bernardino Mountains of southern California. They should perhaps be checked with the subspecies *densestriata* Pilsbry, but to the time of writing I have been unable to compare them with either the description or authentic material of that form.

19. *Vertigo ovata* (Say).—This species, so widespread and abundant in states more to the eastward, is turning up with increasing frequency in collections from the northwest as far south as northern California.

20. *Gastrocopta pentodon* (Say).—Far-western records of this common and very widespread eastern species are both few and extremely scattered. The nearest extant record to the present one is probably that of Dall (1905:28) at Laggan, Alberta.

21. *Succinea* cf. *hawkinsii* Baird.—Most of the Succineas present are imma-

ture shells of *S. hawkinsii* or some species closely allied thereto, but as I have seen no other specimens of Baird's species, and the latter when adult is far larger than the largest of these, it probably would not be safe to attempt a more precise determination. A few of the shells have a shorter and rounder aperture and body-whorl than the others and might conceivably represent still another form.

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Studies on the Parasitic Helminths of the North Central States. I. Helminths of Sciuridae*

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It is accepted that a fair degree of completeness is being achieved in our knowledge of North American mammals and birds. It can be assumed that nearly all the described species of the higher vertebrates are parasitized by helminths, but many of these helminths probably remain undescribed, and little is known of their geographical distribution. Very little information is available on the incidence of the parasites, or their effect on the host.

Information concerning host-parasite relations should be of interest to workers in wildlife management, in order to have a more nearly complete knowledge of the ecology involved. The writers concede that from the standpoint of helminthology alone, information pertinent to life cycles is of basic importance at present. However, we hope that survey data can be used to advantage by those wishing to conduct such research.

Over the past few years, beginning in 1942, we have made examinations of a large number of animals representative of the fauna of the North Central States, and it is our intention to present the resulting data, by host group, as they are completed. While it is true, in some cases, that additional examinations would yield information of value, circumstances have often made it necessary to discontinue work with a given group after studying only a fairly representative series of specimens. In order to use the time most economically, we have followed the practice of collecting without concentration on a single group or species. This has also contributed in part to a lack of an adequate number of animals from some localities.

The planning of this study, and most of the Ohio and Michigan collecting, was carried out by the senior author, who is also responsible for cestode and trematode identifications. The junior author identified the nematodes encountered, and assisted in collecting. We regret that there were no specialists in such fields as entomology, bacteriology, and mammalogy available to make further use of the material which came through our hands. Whenever possible, study skins and skulls of this and other material were deposited in recognized collections.

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** Formerly of the University of Wisconsin.

The carefully-organized collaboration of Elton, Ford, Baker, and Gardner (1931) in their investigations of the diseases and parasites of rodents should stand as a model for this type of study.

Source of Material

A total of 325 sciurids, collected by the writers in Ohio, Michigan, Illinois, and Wisconsin, was examined, among which the following were represented: fox squirrel, *Sciurus niger rufiventer* Geoffroy; southern gray squirrel, *Sciurus c. carolinensis* Gmelin; northern gray squirrel, *Sciurus carolinensis leucotis* Gapper; red squirrel, *Tamiasciurus hudsonicus* subspp.; chipmunk, *Tamias striatus* subspp.; eastern flying squirrel, *Glaucomys v. volans* (L.); northern flying squirrel, *Glaucomys sabrinus macrotis* Mearns; 13-lined ground squirrel, *Citellus t. tridecemlineatus* (Mitchill); Franklin's ground squirrel, *Citellus franklini* (Sabine); woodchuck, *Marmota monax* subspp. Certain of these were not identified to subspecies, since this has little value in the present study, and such identifications are often difficult without large series for comparison. The host names are according to Bole and Moulthrop (1942), and Burt (1946).

In addition to the specimens mentioned above, through the kindness of Dr. Clarence E. Mickel, a number of helminths from Minnesota sciurids was made available to us for examination. This collection included the helminths from 11 least chipmunks, *Eutamias minimus jacksoni* Howell; 1 gray squirrel, *S. carolinensis hypophaeus* Merriam; 3 fox squirrels, *S. niger rufiventer;* one 13-lined ground squirrel, *C. t. tridecemlineatus;* and 3 woodchucks, *M. monax* subsp. With the author's permission we have also included the unpublished results of the survey of Ohio squirrels by Katz (1938), which was based on the examination of 72 southern gray squirrels, *S. c. carolinensis;* and 16 fox squirrels, *S. niger rufiventer.*

The localities from which the material was examined are shown on the map (Fig. 1) to the nearest county. The counties, according to the numbers used to designate them, are as follows:

OHIO
1. Butler
2. Darke
3. Wood
4. Seneca
5. Wyandot
6. Marion
7. Union
8. Delaware
9. Franklin
10. Fairfield
11. Scioto
12. Ashtabula

MICHIGAN
13. Ingham
14. Cheboygan

ILLINOIS
15. McHenry

WISCONSIN
16. Barron
17. Buffalo
18. Jackson
19. Juneau
20. Sauk
21. Dane
22. Columbia
23. Dodge
24. Fond du Lac
25. Shawano

MINNESOTA
26. Fillmore
27. Scott
28. Hennepin
29. Ramsey
30. Carlton
31. St. Louis
32. Cook
33. Carver

The localities are referred to below in the separate considerations of the helminths, in order to show their distribution. The parasite distribution is

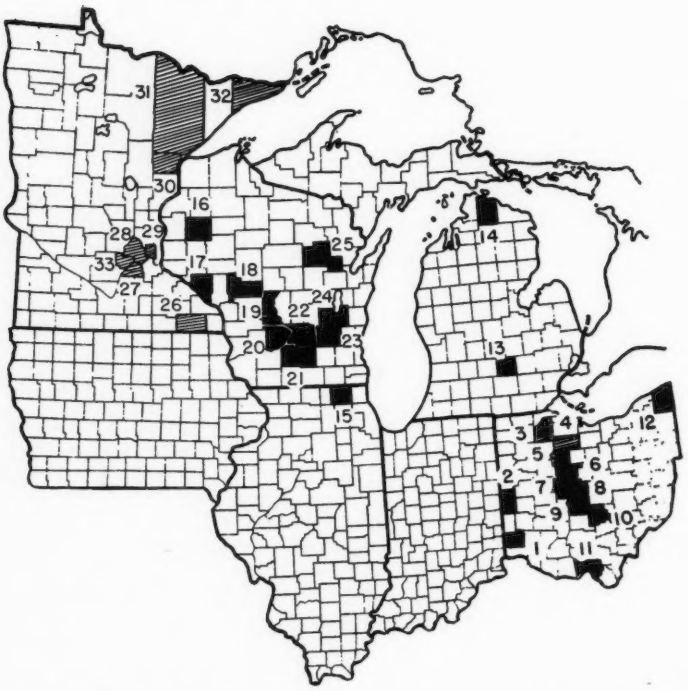

Fig. 1.—Map of the North Central States showing localities from which material for this study was obtained. Counties in solid black are those from which the host animals were examined by the writers.

considered irrespective of host species, since the number of host animals examined was not sufficient to allow otherwise.

Results

A total of at least 33 species of helminths was encountered during the course of the present study. The results of the examinations made by the writer are shown in Table 1. Data taken from the work of Katz (1938) are listed in Table 2, and those regarding the Minnesota material are shown in Table 3. It should be noted here that the total number of Minnesota sciurids examined was not known, so no information is available concerning incidence of helminths from the animals of that area.

The helminths are considered separately below, according to species. The numbers in parentheses refer to the counties listed above, and indicated on the map (Fig. 1).

CESTODA

Nine species of cestodes were collected by the writers; of these, 6 were adult, and 3 were larval forms. Cestodes, in general, were uncommon in tree squirrels, but abundant in ground squirrels from some localities.

ANOPLOCEPHALIDAE

1. *Catenotaenia pusilla* (Goeze, 1782) (11, 14, 18, 21). Found in the small intestine of the host, this cestode was collected by the writers from one fox squirrel, and from three northern flying squirrels. Katz (1938) recorded what was probably this species from the southern gray squirrel and the fox squirrel. All infections were light, consisting of but a single worm each, except for one animal which contained two worms. The life cycle of *C. pusilla* has recently been elucidated by Joyeaux and Baer (1945), and the intermediate host was shown to be a mite. These workers, as a result of their investigations, removed the genus from the family Dilepididae, and placed it in the family Anoplocephalidae.

2. *Andrya sciuri* Rausch, 1947 (18). Parasitic in the small intestine of the host, the present species was taken twice from the northern flying squirrel. Another member of the genus, *A. primordialis* Douthitt, 1915, has been recorded from North American squirrels, but we did not encounter it. Unfortunately, we were not able to obtain enough specimens of the host animal to determine how commonly *A. sciuri* occurs, or what its geographical distribution might be. Although the life cycle of cestodes of this genus is not known, the intermediate form is possibly found in a mite, as is the case with the other members of the family where the life cycle is known.

The helminths found in the two species of flying squirrels examined by us differed sufficiently that it would be of considerable interest to examine animals from the area where the ranges of these species overlap.

HYMENOLEPIDIDAE

3. *Hymenolepis diminuta* (Rudolphi, 1819) (3, 11, 16, 18, 21, 23, 24, 25, 29). Parasitic in the small intestine of the host. Although common in ground squirrels in some areas, this cestode occurred rarely in tree squirrels. Katz (1938) recorded what was probably this species from the southern gray squirrel and fox squirrel in Ohio; we collected the species only in Wisconsin, however. As many as 42 specimens of this cestode were taken from the small intestine of a single 13-lined ground squirrel; ordinarily from 1 to 6 specimens were present. The tree squirrels, Franklin's ground squirrel, and the chipmunk infected with this species contained a single specimen each. The two specimens examined from tree squirrels were much larger than any of the others.

McLeod (1933) described *Hymenolepis citelli* from ground squirrels in Manitoba. Except for the single specimen from the chipmunk, discussed below, all specimens of *Hymenolepis* collected by us from squirrels agree closely with McLeod's description. However, we were not able to differentiate them from specimens of *H. diminuta* taken from Ohio rats. Since the characters

used by McLeod seem to be somewhat variable, we recommend that *H. citelli* (McLeod, 1933) be considered a synonym of *H. diminuta* (Rudolphi, 1819). Hughes (1941) did not consider *H. citelli* in his key to the species of the genus *Hymenolepis*.

4. *Hymenolepis* sp. (21). Found in the large intestine of the host, a single, incomplete specimen was taken from a chipmunk collected at Madison, Wisconsin. Specific determination was not possible, but it resembled somewaht *H. fraterna* Stiles, 1906, in its morphological details.

MESOCESTOIDIDAE

5. *Mesocestoides latus* Mueller, 1928 (13). A single large worm belonging to this species was taken from the small intestine of a fox squirrel, collected at East Lansing, Michigan. This parasite has not previously been recorded from squirrels, and certainly it is not a common parasite of this host group. Although a considerable number of fox squirrels (44) was examined from the same area, and most of these from the same woodlot from which the infected animal was collected, no other infection by this cestode was detected. It is worthy of note that other mammals (raccoon and opossum), collected from the same woodlot, were rather commonly infected with *M. latus*. In view of the life cycle of this group of cestodes (Schwartz, 1927), it seems unlikely that squirrels ordinarily would be exposed to infection. It was of interest to note that many gravid segments were present in the strobila of this specimen.

TAENIIDAE

6. *Taenia pisiformis* (Bloch, 1780) (13). A single infection by this parasite was recorded. Eleven cysticerci were removed from the body cavity of a fox squirrel. Brown and Yeager (1945) reported the species from squirrels in Illinois, but it cannot be considered a common parasite of squirrels. Since there was a high infection of rabbits in the intermediate area, and since dogs were commonly found in the woodlot from which the infected squirrel was collected, it seems that squirrels must ingest numerous eggs which never develop. It would be most interesting to know why this development can take place in certain individuals only, as is apparently the case.

7. *Taenia taeniaeformis* (Batsch, 1786) (13). Larval forms of this cestode were removed twice from liver cysts of the fox squirrel. It has previously been recorded from North American squirrels, but is not a common parasite in this group. It is of interest to note that the two infected squirrels were taken during the winter months of January and February. Concurrent work with the meadow vole (*Microtus p. pennsylvanicus* Ord), of which 345 specimens were examined from a field adjacent to the woodlot where the infected squirrels were collected, showed a definite peak of infection with *T. taeniaeformis* during winter and early spring. Nine per cent of the voles were infected. According to Miller and Gardiner (1934), the presence of cysticerci of this species in rats confers an active immunity which prevents the onchospheres from establishing themselves during any subsequent exposure.

8. *Unidentified cestode.* (13). Fragments of a single cestode were taken from the small intestine of a red squirrel. The condition of these was such that identification was not possible.

9. *Unidentified cysticerci.* (23). Six very small cysticerci, some of which were degenerating, were removed from the liver of a single 13-lined ground squirrel. It is possible that these are larval forms of one of the bird cestodes, such as *Cladotaenia*. Since ground squirrels form a major item in the diet of the badger, one might expect cysticerci of the badger cestode, *Taenia taxidiensis* Skinker, 1935, to be found in these squirrels. When compared with adult worms from badgers, however, it was found that the hooks differed greatly. A double row of 38 hooks was present on the cysticerci; these measured 15 and 6 μ long.

TREMATODA

Trematodes are uncommon in the North American sciurids. We collected only three species belonging to this group.

NOTOCOTYLIDAE

10. *Quinqueserialis hassalli* (McIntosh and McIntosh, 1934) (21). A heavy infection of this species of trematode was encountered in the cecum of a single woodchuck, from which it has not previously been reported. The infected animal had its den at the immediate margin of a large, stagnant pond, and snails, probably ingested with vegetation, were found in the intestine when the autopsy was made. Infection with this parasite might depend much more upon the habitat and food habits of the host than upon natural immunity. In the area covered by us, the meadow vole is the only other host from which we have recorded this trematode.

DIPLOSTOMIDAE

11. *Fibricola nana* Chandler and Rausch, 1946 (13). Two specimens of this trematode were taken from the small intestine of a red squirrel. It is probable that such small helminths as these are often overlooked in routine examinations, since they only can be detected when the intestinal content is examined under the low power of the microscope. The life cycle is not known. As pointed out previously (Chandler and Rausch, 1946) this is apparently the first strigeid to be recorded from sciurids.

BRACHYLAEMIDAE

12. *Scaphiostomum pancreaticum* McIntosh, 1934 (21). One of the few helminths encountered which occurred outside the intestinal tract, *S. pancreaticum* was found in the pancreatic ducts of the chipmunk. This trematode was first recorded (McIntosh, 1934) from northern Michigan. We found it only in Wisconsin, where most of the chipmunks examined were collected. It was found in adult animals only, although several young, nearly full grown, were examined. It is of interest to note that the infected animals were taken near a large lake. It is not clear to us what effect the parasite might have on the host.

NEMATODA

Most of the helminths encountered by us in sciurids belonged to this group. Nematodes occurred in larger numbers than did either cestodes or trematodes.

STRONGYLOIDIDAE

13. *Strongyloides* sp. (13, 16, 20, 21). This nematode was found uncommonly in the small intestine of three species of tree squirrels. Because of its small size, it might be very easily overlooked. Chandler (1942) described *S. robustus* from squirrels in Texas. *S. papillosus* (Wedl) was recorded from the southern gray squirrel by Reiber and Byrd (1942).

TRICHOSTRONGYLIDAE

14. *Citellinema bifurcatum* Hall, 1916 (1, 3, 6, 11, 13, 15, 17, 18, 19, 21, 22, 26, 28, 32). The most common nematode found by us in the sciurids, *C. bifurcatum* has been recorded from several host species over an area extending from Colorado, Wyoming, and Saskatchewan eastward to Maine. It has not been found south of Tennessee and Maryland, nor in east Texas. Infections were usually light in the animals examined by us. In the fox squirrel from 1 to 42 specimens were found, with an average number of 9.

15. *Heligmodendrium hassalli* (Price, 1928) (11, 16, 17, 18, 20, 21). Although fairly common in Wisconsin, the writers did not find this species in sciurids collected from the rest of the region. Katz (1938) recorded this species only from the southern tip of Ohio, where its incidence appeared high, and Price (1928) recorded it from Maryland. Harkema (1936), Chandler (1942), and Graham and Uhrich (1943) have reported this nematode from areas farther south than those from which *C. bifurcatum* has been recorded. Data concerning the distribution of both species appear to be far from complete. Infections were generally light in the three species of tree squirrels from which we recorded this helminth, although in one case 438 worms were taken from a single fox squirrel.

16. *Trichostrongylus calcaratus* Ransom, 1911 (20, 21). This nematode, a common parasite of rabbits, was found in the fox and gray squirrels in Wisconsin. A single male, with unusually short spicules, but which otherwise resembled this species, was found in the chipmunk. *T. calcaratus* is, however, evidently better adapted to rabbits than to squirrels. We did not find it in squirrels in Ohio or Michigan, although it has been taken from rabbits from both areas, and in some cases from immediate woodlots from which squirrels were collected. In Wisconsin a maximum of 2 specimens was removed from a single sciurid host; on other occasions isolated male or female specimens occurred. In one instance, a single male *T. calcaratus*, in conjunction with 33 *Strongyloides* females, caused considerable difficulty in the identification of the latter. Graham and Uhrich's (1943) finding of 11 specimens in a single fox squirrel would indicate that this animal may serve as host to moderate numbers of this helminth, on occasion. The life cycle of *T. calcaratus* is direct.

17. *Obeliscoides cuniculi* (Graybill, 1924) (6, 7, 13). Apparently a common parasite of the woodchuck in Missouri, Ohio, Michigan, and Minnesota (Rausch and Tiner, 1946). According to the report by Dalke (1942), *O. cuniculi* shows a definite decrease in the cottontail during the winter months. Erickson (1944), however, found high infections in the snowshoe hare in the spring (March). While we unfortunately had an insufficient number of woodchucks to check this, it was noted that all infected woodchucks were taken during the month of July, or later in the summer. This perhaps indicates that the woodchuck is relatively free from this parasite when emerging from hibernation. We found 9 woodchucks, collected before July 1, to be free from this parasite, while 8 animals, collected after this date, were infected, and 4 were uninfected.

18. *Boehmiella wilsoni* Lucker, 1943 (17, 21, 33). Interesting questions as to the epidemiology of *B. wilsoni* seem to be posed by the fact that infections with it were rare and minimal. Five out of a total of 39 gray and fox squirrels taken in the vicinity of Madison, Wisconsin, were infected with a single female each. We did not find this parasite in the rest of Wisconsin, but a single male came from Minnesota. United States National Museum records would indicate that it was collected on three occasions from the southeastern states of West Virginia, Virginia, and Georgia during the years 1897-1943 (Lucker, 1943). The unusually large size of this trichostrongyle makes its detection almost inevitable when the stomach wall and contents are examined with ordinary care.

OXYURIDAE

19. *Enterobius sciuri* Cameron, 1932 (7, 13, 15, 21). This was the common helminth parasitic in the eastern flying squirrel. It was of especial interest that, from an area with a radius of about one-half mile, 73 sciurids of 5 species were taken (East Lansing, Michigan), of which only 8 were infected with this worm. Six of 11 flying squirrels and 2 of 53 fox squirrels were parasitized by *E. sciuri*. Two chipmunks, 5 red squirrels, and 2 woodchucks were not infected. Of two Wisconsin fox squirrels that harbored this nematode in the cecum, one contained only a gravid female, while the other was extremely emaciated, apparently because of a severe case of mange (a condition rather commonly observed by us in at least 3 squirrel species, and which on a few occasions obviously was the cause of the death of the host), and harbored several hundred *E. sciuri* of all ages, including 40 gravid females. It has been collected from the eastern flying squirrel in Ohio and northern Illinois, but we have so far failed to find the northern flying squirrel infected. As far as we have been able to determine, this parasite, described from the American gray squirrel in Scotland, has not previously been recorded from this continent. Our data would indicate that it is an American species, and that the flying squirrel is the normal host in the North Central States. In all cases, the nematode was found in the cecum of the host. Future workers are cautioned to use careful sedimentation methods, and to examine the sediment under the low-power microscope, in order to find this helminth, which is readily overlooked because of its extremely small size. Life cycle

studies on *E. sciuri* might be of interest, since it is remotely related to a human parasite.

20. *Syphacia thompsoni* Price, 1928 (14, 18). This nematode occurred in all of the 5 northern flying squirrels examined by us, but it was not found in the eastern flying squirrel. Price (1928) described *S. thompsoni* from the latter species in Virginia. The persistent failure of North American investigators to find this parasite in other sciurids might indicate a high degree of host specificity for flying squirrels. However, Li (1933) has reported *S. thompsoni* from *Sciurus vulgaris* and *Sciurotamia davidianus* in China.

21. *Syphacia* sp. (32). Found only in the cecum and large intestine of the least chipmunk, this nematode appears to represent an undescribed species. Its description is being undertaken by the junior author. We have no idea of the distribution of this helminth, since the host animal was not obtained from Michigan and Wisconsin where, in the area considered, it also occurs. The report of *Syphacia* sp. in large numbers in the California ground squirrel by Linsdale (1946) and the finding of a single *S. obvelata* in *Eutamias amoenus* by Rankin (1945) are of interest, especially since females of the present species are not easily distinguished from *S. obvelata*.

22. *Citellina marmotae* Manter, 1930 (14, 30). Manter (1930) has recorded this helminth from Maine, and we are able to extend its range to northern Michigan and Minnesota. Of the two infections found by us, one was quite heavy, with an excess of 400 worms, while the other was lighter, with about 100 worms.

ASCARIDIDAE

23. *Ascaris* sp. (6, 7, 9, 21). Immature ascarids were found by the writers on three occasions. Katz (1938) reported *Ascaris lumbricoides* Linnaeus, 1758, from squirrels, as did Brown and Yeager (1945). However, since Linsdale (1946) has reported what appeared to be *A. columnaris* Leidy, 1856, from the California ground squirrel, *Citellus beecheyi* (Richardson), we do not consider our material adequate for definite specific determination. The squirrels examined by the writer might easily have become infected with either species, since *A. lumbricoides* is a common parasite of swine, and *A. columnaris* is commonly found in some of the carnivores (raccoon, skunk, badger), in the region where the material was collected. It seems questionable whether these ascarids are able to mature in squirrels. Perhaps it can be assumed that *A. laevis* Leidy, 1856, may be identical with one of the above forms rather than with *T. pigmentata* von Linstow, 1897, as has been suggested by Hall (1916). *Ascaris laevis* was described from a single female occurring in the woodchuck.

THALAZIIDAE

24. *Rictularia halli* Sandground, 1935 (21). We are of the opinion that the specimens of *Rictularia* from the gray squirrel and chipmunk in Wisconsin belong to the species of *R. halli* Sandground, 1935, since the males found in these hosts seem to agree with Sandground's description. It may be shown, by the study of additional material, that *R. halli* is identical with the species

discussed below, previously described by McLeod (1933). Infections with *R. halli* were light (1 to 7 worms; average number 2 per host). As has been the usual experience with this genus, far more females than males were recovered. We do not, however, consider this a result of overlooking the males, because of their small size, but rather that it is a peculiarity of the group.

25. *Rictularia citelli* McLeod, 1933 (21, 29). We could not distinguish the females of this species from those of *R. halli;* however, a comparison of the single male collected by us with a male loaned by Dr. McLeod indicated that our material from the 13-lined ground squirrel cannot yet be considered identical with *R. halli.* This species occurred more abundantly in the host than the preceding one (1 to 19 worms; average number 3.6 per host).

26. *Rictularia* sp. (6, 7, 8.) Collected by us only in Ohio, and reported by Katz (1938) from that area, and by Graham and Uhrich (1943) from southeast Kansas, this species closely resembles *R. onychomis* Cuckler, 1939, but differs in morphological details. Additional information concerning some of the species of *Rictularia* will be presented in the near future (Tiner, unpublished data).

SPIRURIDAE

27. *Spirura michiganensis* Sandground, 1935 (21). This nematode was collected only from the chipmunk, in central Wisconsin. It is of interest to note, in connection with the following species, that a considerable number of 13-lined ground squirrels were taken within a quarter of a mile of the locality where the infected chipmunks were collected. None of the chipmunks had more than 3 of these nematodes in the small intestine, with an average number of 2 worms.

28. *Spirura infundibuliformis* McLeod, 1933 (29). A single 13-lined ground squirrel collected at St. Paul, Minnesota, was infected with this species. Dr. A. B. Erickson, St. Paul, Minnesota, should receive credit for the original identification. The number of male pre-cloacal papillae varies from 10 to 12 on each side in this species, and from 5 to 8 in *S. michiganensis.* This difference appears to be the chief means of distinguishing the two forms.

PHYSALOPTERIDAE

29. *Physoloptera* sp. (21, 25, 29). Immature forms belonging to this genus were taken by the writers from the northern gray squirrel, Franklin's ground squirrel, and the 13-lined ground squirrel. It also occurred in the latter species in Minnesota. *Physaloptera massino* Schulz, 1926, has been reported (Morgan, 1943) from the fox squirrel and 13-lined ground squirrel in Wisconsin and Minnesota, and McLeod (1933) has reported the same species from ground squirrels in Canada. These nematodes were uncommon in the animals examined during the course of the present study.

TRICHURIDAE

30. *Trichuris* sp. (21). This nematode occurred twice in the chipmunk, but material was not adequate to allow for specific determination. Members of this genus apparently are uncommon in sciurids of this region, although they may occur commonly in other rodents.

31. *Capillaria* sp. (3, 7, 11, 15, 21). The small size of this parasite, and its tendency to adhere closely to the intestinal wall, may account in part for its seeming scarcity. Although recorded from the northern gray squirrel, Franklin's ground squirrel, chipmunk, and flying squirrel, it occurred commonly in only the last two species, and in greatest numbers (maximum of about 40) in the chipmunk. Katz (1938) recorded *Capillaria* sp. from the fox squirrel and southern gray squirrel in Ohio.

A few specimens of nematodes were obtained, which, usually because of immaturity, could not be identified. These are not considered here, although they are listed in Tables 1 and 3.

ACANTHOCEPHALA

GIGANTORHYNCHIDAE

32. *Macracanthorhynchus hirudinaceus* (Pallas, 1781) (6, 8). A total of 5 adult worms of this species was taken from two fox squirrels, collected in central Ohio, and a single immature specimen was found attached to the mesentery in the body cavity of a chipmunk, from the same area. The occurrence of this helminth in squirrels has previously been reported (Rausch, 1946). The local distribution of this parasite, in its normal host, is not clear. As far as we have been able to determine, it is not found over much of the area considered in this paper.

MONILIFORMIDAE

33. *Moniliformis* sp. (32). A few specimens belonging to this genus occurred in the least chipmunk in Minnesota. The condition of these was such, however, that specific determination was not made. Chandler (1941) recorded *M. clarki* (Ward, 1917) from *Sciurus* and *Citellus* in the "midwestern states," and McLeod (1933) recorded *M. spiradentatis* from *Citellus* spp. in Canada. The status of the last-mentioned species is not clear. The occurrence of *Moniliformis* in North American squirrels has recently been reviewed by Chandler (1947). Helminths of this genus are uncommon in the sciurids of the North Central States, although they occur commonly in squirrels in other areas (Chandler, 1947). We have recorded only one other species of *Moniliformis* from this region, *M. dubius*, collected from moles, *Scalopus aquaticus machrinus* (Rafinesque), in Ohio.

Discussion

Although the ecology of the sciurid hosts has a close connection with their parasitism by helminths, it is doubtful that the changes which have

occurred in the distribution of the squirrels themselves have greatly affected the parasites.

The changes in land use which have taken place since settlement of the region under consideration have strongly influenced the distribution and abundance of the squirrel species. This has been especially evident in the replacement of the gray squirrel by the fox squirrel over much of the area, as clearing of the forest has made suitable habitat for the latter. This has been well described for Michigan by Allen (1943). Except for isolated colonies (e. g. Columbus, Ohio, and Detroit, Michigan) the gray squirrel is now absent from the heavily cultivated, glaciated section of Ohio, and from southern Michigan. In southern Wisconsin both species occur together, and in Illinois this is also the case, with the fox squirrel predominating (Brown and Yeager, 1945).

The 13-lined ground squirrel becomes more abundant with overgrazing of pasture land, and appears to be extending its range eastward, where it is now found to central Ohio. Franklin's ground squirrel is found as far east as the western edge of Indiana. The latter is sporadic in its occurrence in southern Wisconsin, where the specimens examined for the present study were collected.

The red squirrel is found abundantly over Ohio and southern Michigan, especially along streams. This species was quite common in the oak-hickory woodlots in central Ohio, but seems to have decreased during the last few years. In Wisconsin it is uncommon south of the coniferous forests, and probably absent from Illinois, according to Brown and Yeager (1945).

The eastern flying squirrel is widely distributed, but has been reduced in number by the removal of suitable den trees from many woodlots. The northern species has been less disturbed, and appears to be abundant in some parts of the area considered in the present paper.

The woodchuck is widely distributed, and is found in a wide variety of habitats, from deep woods to cultivated fields. We found it especially abundant in central Ohio, and numerous in southern Michigan. It is not, however, common in southern Wisconsin, and we were unable to secure an adequate series from this region. In central Ohio, at least, this species has increased considerably during the past few years, partly as a result, perhaps, of lessened shooting.

The chipmunk is found over much of the region with which we are concerned, but in many areas it is not numerous. This is especially true of central and western Ohio, where, when it does occur, it is uncommon. The destruction of suitable habitat may in part be responsible for this. However, Aldo Leopold states (personal communication) that he has failed to observe this species in an area in central Wisconsin where he has made observations for several years, and where the habitat apparently is quite suitable. The least chipmunk is confined to the northern edge of the region under consideration.

Several questions arise when one considers the incidence and distribution of squirrel helminths over the area from which our material was obtained. Unfortunately, an inadequate number of host animals, a lack of intensive

collecting in some areas, and unequal numbers of animals from the general areas involved make it impossible to treat these matters in detail. Future work, done intensively on a local scale, as well as the examination of many more host animals, will contribute much to the understanding of the epidemiology of the sciurid helminths found in this region.

It is of interest to note that no helminths were taken from 31 specimens of 13-lined ground squirrel taken in central Ohio, but 40 per cent of the 49 specimens collected in Wisconsin were parasitized by helminths. The few Franklin's ground squirrels examined from southern Wisconsin were lightly parasitized. McLeod (1933), who examined 236 specimens of three species of the genus *Citellus* in Canada, also found relatively fewer parasites in this species. The question arises whether mammals collected from marginal range may show differences in the extent to which they are parasitized, when compared with specimens collected from areas representing more nearly optimum conditions.

It has been found in some cases (Erickson, 1944) that helminth parasites of a species increase as the host approaches the greatest density in the population cycle. We do not have sufficient sciurid material to allow any consideration of this; neither do the sciurids of this region show the spectacular fluctuations in number seen in certain other mammals. However, we have not found any definite indication of this in other host animals. Of 345 meadow voles, *Microtus p. pennsylvanicus* Ord, examined over a period of 13 months from one area, of which time 9 months preceded a typical abrupt decrease in number of animals, there was no evidence of unusual parasitism when compared with about 100 voles collected during the previous two years from other areas, during population lows. At the time of the population decrease, even animals heavily infected with such helminths as *Protospirura* sp. showed no evidence, as far as we could determine, of physical injury.

A total of 21 foxes examined during the unusually high population density of the winter of 1946-1947 also showed no evidence of an abnormal degree of parasitism. Of these animals, all but one were parasitized by helminths; 10 foxes contained *Physaloptera* sp. in the stomach, with an average of 8.5 worms per animal; 6 animals were infected with *Taenia* sp., with an average of 4.6 worms per animal; 12 animals were infected with ascarids, with an average of 21 worms per animal. The part played by helminths, if any, in connection with cyclic fluctuations of the numbers of host animals is certainly not clear.

The sciurids collected in Wisconsin were, both quantitatively and qualitatively, more heavily parasitized than those collected in Ohio and Michigan. However, since equal numbers were not collected each year from each area, it is impossible to determine the amount of variation in the degree of parasitism from year to year.

It is of interest to note that certain of the helminths (*Impalaia* sp. and *Mecistocirrus* sp.) recorded by Brown and Yeager (1945), from squirrels in Illinois, were not collected by us. Certain other omissions from our list can be attributed in part to geographical distribution of the parasite, or its host.

We observed no macroscopic lesions, clinical symptoms, or any injury to

the sciurids examined by us attributable to helminth infections, and we assume that the physical condition of the parasitized animals was normal. McLeod (1933) states that certain of the squirrel helminths recorded by him often have a detrimental effect on the host, but our data do not support this. Concurrent studies on other groups of mammals and birds definitely tend to substantiate our conclusion.

The following data, while meager, are of interest. Of 59 fox squirrels weighed, the 39 non-parasitized specimens averaged 702.1 grams, while the 20 parasitized animals averaged 743.5 grams. Most of these specimens were taken during the winter and early spring. One fox squirrel, the most heavily infected individual encountered by us, contained the following helminths: *T. calcaratus*, 1 specimen; *C. bifurcatum*, 2 specimens; *H. hassalli*, 438 specimens; *Strongyloides* sp., 33 specimens. It is of interest to note that this animal weighed 820.0 grams, and, as far as we could determine, was in excellent physical condition.

Of 27 specimens of 13-lined ground squirrel weighed (males only, because of the great difference between the weights of the sexes) 13 negative animals averaged 159.3 grams, while 14 parasitized animals averaged 159.9 grams. In the case of the ground squirrel, the animals were all adults which had hibernated during the previous winter, and which were taken in the spring before reproduction began.

Species of helminths are not considered in the above examples. The slight differences in the average weights probably would not have occurred if based on a larger series of animals. These data are meant to serve only as an indication that we could observe no appreciable difference in the physical condition of the parasitized and non-parasitized animals, and we do not imply that the data have statistical value.

There can be no question that if young animals were exposed to heavy infections, at least with some of the trichostrongyles, fatalities would result. This has already been shown by Sarles (1932), using rabbits, for one of the species found by us (*T. calcaratus*), and it is a generally accepted principle relating to domestic animals. Our data indicate that in the North Central States, during the years and for the areas considered, the helminths were only potential mechanisms of population control. The trichostrongyles rarely exceeded 10-15 specimens per host. However, Harkema (1936) consistently found about 100 specimens of *H. hassalli* per animal in the southern gray squirrel in North Carolina. Some of these helminths may be more important in other areas.

Our results indicate that some of the internal parasites are able to survive the winter in at least some of the sciurids which hibernate (13-lined ground squirrel and Franklin's ground squirrel), since several of these were parasitized in the spring when collected just after emergence, and before any of the helminths could have matured from newly-ingested larvae.

This paper can only be considered a beginning in the study of the helminths parasitic in squirrels. Future examinations of more material over a wider area may change the present outlook.

ADDITIONAL OBSERVATIONS

After this paper had been submitted for publication, one of us (R. R.) had the opportunity to collect specimens for parasitological study in Manitoba. Certain of the data resulting from these examinations are of interest in connection with what has already been presented above.

Citellinema bifurcatum was found to be a common parasite of the northern red squirrel, *Tamiasciurus h. hudsonicus* (Erxleben), as far north as Garland, Manitoba. It was also recorded from Richardson's ground squirrel, *Citellus richardsonii* (Sabine) from this area and from farther south, at Ochre River, Manitoba. This nematode was recorded from the latter host by McLeod (1933).

Seventeen specimens of *Trichuris* sp. were also taken from a Richardson's ground squirrel at Ochre River. This nematode was not recorded by Dr. McLeod in his survey of ground squirrel parasites.

While investigating an outbreak of botulism in water birds at the south end of Lake Dauphin, near Ochre River, two specimens of *C. richardsonii* were collected. The burrows of these animals were on the immediate margin of a small stream, which ran through an area which had been inundated for some months. One of these animals, about two-thirds grown, was found to be infected with *Plagiorchis proximus* Barker, 1915. Fourteen trematodes were taken from the small intestine of this animal. *Plagiorchis proximus* is a common parasite of the muskrat, but apparently has not previously been recorded from Richardson's ground squirrel. Muskrats occurred in the area from which the infected animal was collected.

We were fortunate in being able to record *Ascaris lumbricoides* from a fox squirrel collected in St. Croix County, Wisconsin, on September 9, 1947. A mature male, measuring 174 mm long, with over 50 pairs of precloacal papillae was taken from the small intestine of the animal, along with a smaller, immature specimen.

This provided our first opportunity to verify the specific identity of the *Ascaris* from squirrels of the North Central States. It would seem probable that this parasite was of porcine rather than human origin, since hogs are abundant and frequently infected with ascarids, over the region studied. Whether *Ascaris columnaris* can also infect squirrels remains to be checked experimentally, or confirmed by field observation.

We wish to call to the attention of those interested in the epidemiology of *Ascaris lumbricoides* that we still lack evidence that tree squirrels ever serve as reservoirs of infection. The small size of the lumen of the squirrel intestine as compared with the cross-sectional area of the adult worm would seem to preclude the chances of fertilized eggs being distributed on a very large scale.

So far as we have been able to determine, there is no report of *A. lumbricoides* ova being found in any sciurid. Baylis and Daubney (1922) failed to consider the question, and specimens reported by Katz (1938), and Graham and Uhrich (1942) were immature. Ova were absent from an adult female collected by Brown and Yeager (1945) (personal communication from Dr. L. J. Thomas).

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TABLE 1.—Animals examined by the writers.

Host	No. examined	Parasite	No. infected
Sciurus niger rufiventer	94	*Taenia taeniaformis*	2
		Taenia pisiformis	1
		Hymenolepis diminuta	2
		Catenotaenia pusilla	1
		Mesocestoides latus	1
		Rictularia sp.	2
		Ascaris sp.	2
		Citellinema bifurcatum	21
		Heligmodendrium hassalli	5
		Trichostrongylus calcaratus	2
		Boehmiella wilsoni	2
		Strongyloides sp.	2
		Enterobius sciuri	4
		Macracanthorhynchus hirudinaceus	2
Sciurus c. carolinensis	6		00

TABLE 1.—(*Continued.*)

Host	No. examined	Parasite	No. infected
Sciurus carolinensis leucotis	27	*Rictularia halli*	3
		Citellinema bifurcatum	8
		Heligmodendrium hassalli	5
		Trichostrongylus calcaratus	3
		Boehmiella wilsoni	3
		Strongyloides sp.	4
		Physaloptera sp.	1
		Capillaria sp.	2
Tamiasciurus hudsonicus	19	*Fibricola nana*	1
		Unidentified cestode	1
		Rictularia sp.	1
		Ascaris sp.	1
		Citellinema bifurcatum	5
		Heligmodendrium hassalli	1
		Strongyloides sp.	1
Tamias striatus	43	*Scaphiostomum pancreaticum*	3
		Hymenolepis diminuta	1
		Hymenolepis sp.	1
		Rictularia halli	9
		Trichostrongylus sp.	1
		Spirura michiganensis	6
		Trichuris sp.	2
		Capillaria sp.	9
Glaucomys v. volans	20	*Citellinema bifurcatum*	1
		Enterobius sciuri	12
		Capillaria sp.	6
Glaucomys sabrinus macrotis	5	*Catenotaenia pusilla*	3
		Andrya sciuri	2
		Citellinema bifurcatum	2
		Syphacia thompsoni	5
Citellus t. tridecemlineatus	80	*Hymenolepis diminuta*	13
		Cysticercus sp.	1
		Rictularia citelli	9
		Physaloptera sp.	2
Citellus franklini	10	*Hymenolepis diminuta*	1
		Physaloptera sp.	1
		Capillaria sp.	1
Marmota monax	21	*Quinqueserialis hassalli*	1
		Citellinema bifurcatum	1
		Obeliscoides cuniculi	8
		Citellina marmotae	2

TABLE 2.—Animals examined by Katz.

Host	No. examined	Parasite	No. infected
Sciurus niger rufiventer	16	*Hymenolepis* sp.	1
		Citellinema bifurcatum	4
		Heligmodendrium hassalli	2
		Rictularia sp.	1
		Capillaria sp.	1
Sciurus c. carolinensis	72	*Catenotaenia* sp.	4
		Hymenolepis sp.	4
		Rictularia sp.	7
		Ascaris lumbricoides	1
		Citellinema bifurcatum	25
		Heligomodendrium hassalli	50
		Capillaria sp.	1

TABLE 3.—Helminths from Minnesota collection.

Host	No. examined*	Parasite	No. infected
Sciurus niger rufiventer	3	*Citellinema bifurcatum*	1
		Boehmiella wilsoni	1
		Unidentified trichostrongyle	1
Sciurus carolinensis hypophaeus	1	*Citellinema bifurcatum*	1
		Unidentified trichostrongyle	1
Citellus t. tridecemlineatus	1	*Hymenolepis diminuta*	1
		Rictularia citelli	1
		Spirura infundibuliformis	1
		Physaloptera sp.	1
Marmota monax	3	*Citellina marmotae*	2
		Unidentified oxyurid	1
Eutamias minimus jacksoni	11	*Rictularia* sp.	1
		Citellinema bifurcatum	2
		Syphacia sp.	8
		Moniliformis sp.	1

* The number of negative animals examined is unknown.

A New Trichostrongylid Nematode from the Pika, Ochotona princeps figginsi*

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The nematodes described in this paper were collected from Figgins' pika, *Ochotona princeps figginsi* (Allen) in the summer of 1947 at the Rocky Mountain Biological Laboratory near Crested Butte, Gunnison County, Colorado. The pikas, sometimes referred to as "rock rabbits" or "conies," were taken from rock slides at elevations of 9,500 feet and above. Of 27 pikas examined by the writer and other students at the laboratory (namely George W. Kelley, Gerald K. Menzie, and John W. McDowell), 14 contained nematodes in the stomach. The number present varied from 1 to 15, the average number being 6. The specimens were killed in hot 70% alcohol and cleared in lacto-phenol solution. Glycerine, even when added very gradually, caused collapse of the body wall. The study was made under the direction of Dr. H. W. Manter, whose helpful suggestions are gratefully acknowledged.

The nematodes are members of the family Trichostrongylidae Leiper, 1912 and may be placed within the sub-family Graphidiinae Travassos, 1937 on the basis of the location of the vulva near midbody, the divergent uteri, the ending of the tail of the female in a single, simple point, the filiform spicules, and the general arrangement of the bursal rays.

In his diagnosis of the Graphidiinae, Travassos also includes the presence of pre-bursal papillae and a telamon, and the lack of a cephalic cuticular inflation. He states that a gubernaculum is absent—"gubernaculo ausente"—but this is apparently an error since a gubernaculum is described as present in all genera to date except *Nochtia* Travassos & Vogelsang, 1929. The presence of a telamon is not mentioned in the descriptions of three species, namely *Graphidium strigosum* (Dujardin, 1845) Railliet & Henry, 1909; *Graphidioides affinis* (Megnin, 1895) Cameron, 1923; and *Graphidioides mazzai* Lent & Freitas, 1935. A cephalic cuticular expansion is possessed by all three species of *Graphidiops* Lent & Freitas, 1938. *Nochtia nochti* Travassos & Vogelsang, 1929 (the only species in the genus) has a cephalic cuticular inflation and lacks pre-bursal papillae and a gubernaculum. In view of the discrepancies shown by the above species with Travassos' diagnosis, it is believed that the specimens from the pika, although they are at variance with his diagnosis in the lack of pre-bursal papillae, a gubernaculum, and a telamon, may correctly be included among the Graphidiinae. It is suggested that his diagnosis of this sub-family be altered to allow the absence of pre-bursal papillae, gubernaculum, and telamon, and the presence of a cephalic cuticular expansion.

The sub-family Graphidiinae at present contains the genera *Graphidium*

* Studies from the Department of Zoology, University of Nebraska, No. 232.

Railliet & Henry, 1909; *Graphidioides* Cameron, 1923; *Graphidiops* Lent & Freitas, 1938; and *Nochtia* Travassos & Vogelsang, 1929, the last named genus being placed in this group provisionally by Travassos. My specimens differ from each of these genera in several respects (see discussion). Hence a new genus, *Graphidiella*, is proposed for them.

Graphidiella n. gen.

Generic diagnosis.—Graphidiinae. Cuticula with fine transverse striae and numerous longitudinal "lines." No cephalic cuticular expansion. Cervical papillae present. Nerve ring located in front of excretory pore. Female reproductive system with two divergent uteri. Vulva situated in the third body quarter from the anterior end, the body not narrowing abruptly in the postvulvar region. Ovejectors approximately equal, each with three distinct bulbs. Eggs with thin, unmarked shells; eggs near the vagina contain embryos in the morula stage. Tail terminates in a relatively obtuse, conical point.

Male with a symmetrical, trilobed bursa, the dorsal lobe being but slightly differentiated from the lateral lobes; bursal membrane continuous across ventral surface. All rays travel relatively straight throughout their length and but little divergence occurs within the ventral and lateral ray groups. Ventral rays arise in a short common trunk; they are about equal in size and only slightly divergent. Lateral rays have a short common trunk, are approximately equal in size, and are slightly divergent, the group lying about midway between the dorsal and the postero-lateral rays. The dorsal ray is longer and wider than the other rays and divides near its tip, each division being bifurcate. Spicules equal or sub-equal, long and filiform, with fasciculate points, and bearing transparent alate processes. Genital cone well developed. Gubernaculum and telamon absent. *Type species: Graphidiella ochotonae* n. sp.

Graphidiella ochotonae n. sp.*

Specific diagnosis.—In the living condition the worms are reddish in color. White convoluted stripes are visible through the body wall of the female. When preserved, the specimens lose their red color.

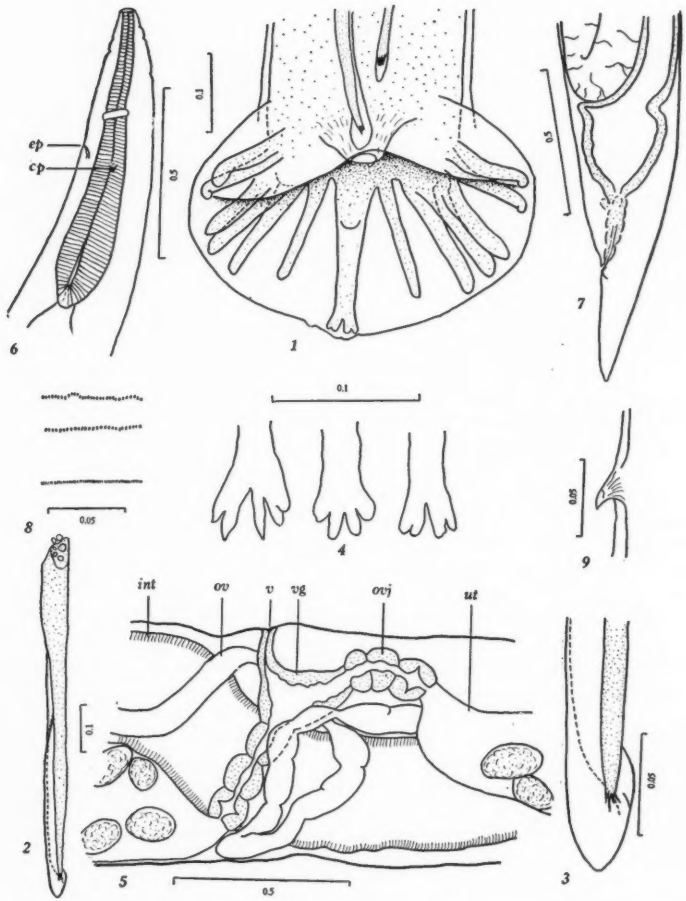
Cuticula with extremely fine transverse striae, barely visible even under oil immersion. More conspicuous are the numerous longitudinal cuticular "lines," from 18 to 52 μ apart. They occur throughout the length of the body, though no one 'line" is continuous through the entire distance. The number present at midbody is approximately 40. Under low power these "lines" present a beaded appearance, and when examined under high power are seen to be made up of a series of minute transverse units, roughly rectangular in shape, and numbering from 40 to 50 in a distance of 100 μ. In certain of the "lines," these units are much finer and about twice as numerous (Fig. 8). In the cervical region the "lines" develop into prominent, continuous ridges. No cephalic expansion of the cuticula is present. The oral aperture is followed by a buccal cavity, 15 to 18 μ deep. The claviform esophagus averages 0.76 mm in length

* Measurements are based on 12 males and 6 adult females. Where maximum and minimum measurements are given, the average follows in parentheses.

and 0.13 mm in maximum width in the female and 0.70 mm in length and 0.12 mm in maximum width in the male. The nerve ring averages 0.27 mm from the anterior end in the female and 0.28 mm in the male. Prominent lateral, posteriorly directed cervical papillae are located 0.49 mm from the anterior end in the female and 0.53 mm from the anterior end in the male. The distance of the ventral excretory pore from the anterior end is 0.46 mm in the female and 0.50 in the male (Fig. 6).

Female.—Length, 23.2 to 17.7 mm (20.7 mm); maximum width (in the vicinity of the vulva), 0.78 to 0.52 mm (0.67 mm). The vulva does not protrude from the body surface and is located a short distance behind the middle of the body, being 10.8 to 7.0 mm (9.1 mm) from the posterior end. In immature females the vulva was found slightly farther back, about $^3/_5$ of the total length from the anterior end. The vagina gives rise to two sub-equal, muscular, divergent ovejectors, each ovejector consisting of three bulbs, the wall of the bulb farthest from the vagina in each case possessing a marked internal constriction (Fig. 5). The uteri and ovaries are much convoluted, extending through most of the body length. Eggs in the uteri measure 0.203 to 0.155 mm (0.180 mm) by 0.103 to 0.081 mm (0.092 mm), have thin-walled shells without markings but with slight polar thickenings, and contain embryos in the morula stage. The intestine terminates in a short rectum averaging 0.19 mm in length. The anus is located 0.38 to 0.30 mm (0.33 mm) from the posterior end, and the tail ends in a relatively obtuse point (Fig. 7).

Male.—Length, 17.4 to 11.1 mm (13.9 mm); maximum width, 0.51 to 0.36 mm (0.47 mm). The testis begins at a point about $^2/_5$ of the total length from the anterior end, extending backward parallel to the intestine without convolution. Pre-bursal papillae are not present. The bursa is symmetrical and trilobed, the dorsal lobe being but slightly differentiated from the lateral lobes. The bursal membrane is continuous across the ventral surface. Some striking features about the bursal rays as a whole are their uniformity in size (with the exception of the dorsal), the lack of divergence within the ray groups, the straightness and uniformity of width of each ray throughout its length, and the relatively blunt ends of the rays (Fig. 1). The ventral rays arise in a short common trunk and extend to near the bursal margin, diverging very slightly. The lateral rays arise in a short common trunk and extend straight to near the bursal margin, again with but slight divergence. They are about equal in size and lie approximately midway between the latero-ventral and the externo-dorsal rays. The externo-dorsal ray arises separately at the base of the dorsal, lies about midway between the postero-lateral and the dorsal, and does not extend to so near the bursal margin as the other rays. The dorsal is the longest and widest of the rays, and divides near its distal end, each branch being bifurcate. In some specimens these bifurcations are as long as the branches of the original division, giving the impression of four lobes at the end of the dorsal ray. Other slight variations may occur in the branching of the dorsal ray tip (Fig. 4). A conspicuous genital cone is present, bearing two papillae. Neither gubernaculum nor telamon could be detected. The dark brown spicules are long and slender, somewhat wider in the proximal fourth, and terminating



Figs. 1-9. *Graphidiella ochotonae*.—1. Bursa of male (ventral view); 2. spicule; 3. distal end of spicule (enlarged); 4. dorsal ray tips, showing variation in branching; 5. region of vulva of female; 6. anterior end of female (lateral view); 7. posterior end of female (lateral view); 8. longitudinal lines of cuticula; 9. cervical papilla (male).

All figures were drawn with the aid of a camera lucida. The value of the projected scale is indicated in millimeters in each figure.

Abbreviations: cp—cervical papilla, ep—excretory pore, int—intestine, ov—ovary, ovj—ovejector, ut—uterus, v—vulva, vg—vagina.

in a fine but fasciculate point (Figs. 2 and 3). They are equal or sub-equal in length, 0.77 to 0.66 mm (0.71 mm). Each spicule bears transparent alate processes, forming a double fold; one fold arises about midway in the spicule, extends distally to form a leaf-shaped sheath around the tip, then folds under and extends proximally about $^2/_3$ of the spicule length.

The specific name is derived from the host generic name, *Ochotona*.

Host.—*Ochotona princeps figginsi* (Allen).

Location.—Stomach.

Type locality.—Gunnison County, Colorado.

Syntype (*cotype*) *specimens.*—U. S. Nat. Mus., Helm. Coll. No. 37057.

DISCUSSION

Graphidiella differs from all other genera in the Graphidiinae in the possession of not one but three bulbs in each ovejector. It differs from *Graphidium* Railliet & Henry, 1909 in that the body of the female does not narrow abruptly behind the vulva, pre-bursal papillae and a gubernaculum are lacking, the lateral rays do not increase progressively in length and decrease in thickness proceeding posteriorly, the lateral rays and the ventral rays are but slightly divergent, and the externo-dorsal ray does not reach the bursal margin. It is unlike *Graphidioides* Cameron, 1923 in that cervical papillae are present, pre-bursal papillae and a gubernaculum are lacking, the ventral rays are not greatly different in size and are not widely divergent, the externo-dorsal ray does not originate in a short trunk in common with the dorsal, the spicules are fasciculate rather than terminating in an acute point, and the externo-dorsal ray is not adjacent to the postero-lateral ray along most of its length. It is unlike *Graphidiops* Lent & Freitas, 1938 in that no cephalic cuticular expansion is present, well-defined cervical papillae are present, the tail of the female does not terminate in a fine point, the externo-dorsal ray does not turn sharply medially and dorsally in the distal half, the spicules do not terminate in two distinct points, and pre-bursal papillae, a gubernaculum, and a telamon are lacking. It differs from *Nochtia* Travassos & Vogelsang, 1929 in that no cephalic cuticular expansion is present, the bursa of the male does not posses small cuticular "humps" on the inner surface, the antero-lateral ray is not parallel and adjacent to the latero-ventral ray, the dorsal ray does not possess two pairs of lateral branches in addition to a terminal bifurcation, and no telamon is present.

Travassos (1937) lists three lagomorph genera (twelve species) of the family Leporidae as hosts for trichostrongylids. Among these trichostrongylids is *Graphidium strigosum*, which has been reported from *Oryctolagus cuniculus*, *Lepus timidus*, and *Lepus europaeus*. However, I have found no record of a trichostrongylid parasitizing the Ochotonidae. Dickmans (1939) described a nematode, *Murielus harpespiculus*, belonging to the related family Heligmosomidae, from the small intestine of *Ochotona princeps ventorum* in Wyoming. Martin (1943) reports finding "stomach worms" in two out of seven specimens of *Ochotona princeps saxatilis*, taken in the Snowy Range of southeastern Wyoming.

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Schizorchis ochotonae n. gen., n. sp. of Anoplocephalid Cestode*

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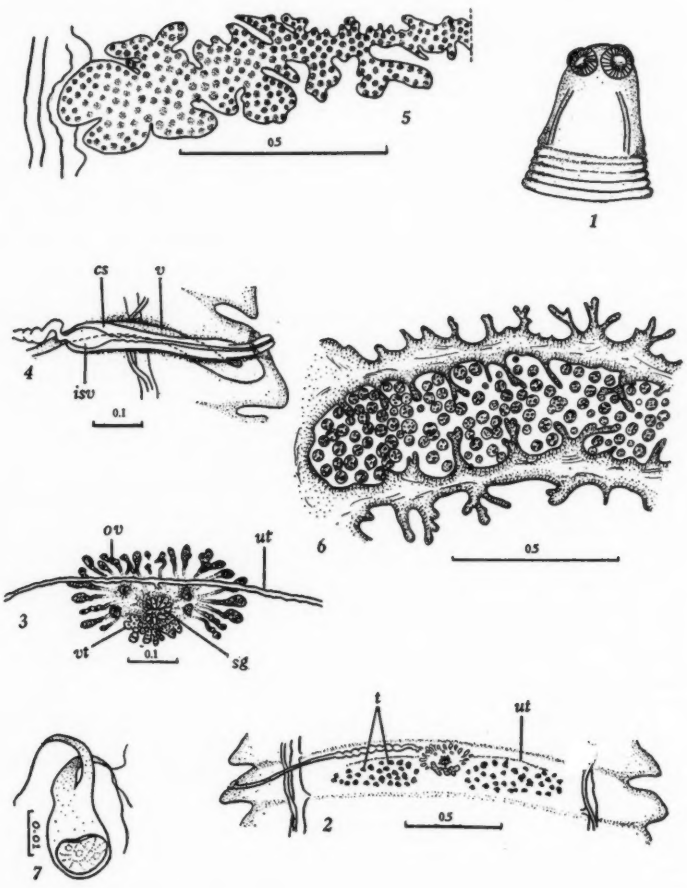
Sixteen specimens of a tapeworm collected from the pika *Ochotona princeps figginsi* (Allen) at the Rocky Mountain Biological Laboratory near Crested Butte, Gunnison County, Colorado, during July and August of 1947, proved to be a new genus and species in the family Anoplocephalidae. Four of 27 pikas examined were infected with the tapeworm. The number of tapeworm in a host varied from 1 to 8. Only 6 of the 16 specimens are mature. The following description is based upon the 6 mature specimens. Frontal, cross, and sagittal sections were made from 2 of the 6 mature specimens.

Schizorchis ochotonae n. gen., n. sp.
Figs. 1-7

Description.—Mature specimens of this tapeworm measure 25.0 to 30.5 mm long by 1.53 to 2.79 mm wide. The scolex is 0.090 to 0.137 mm long by 0.164 to 0.206 mm wide. The circular suckers measure 0.041 to 0.082 mm in diameter; the sucker orifice measures 0.054 to 0.069 mm in diameter. There is no constriction of the neck region; the body widens continuously from the scolex to about the 10th proglottid. The neck measures about 0.137 mm long. The genital pores are irregularly alternate, opening slightly posterior to the middle of the lateral margin of the proglottid. The ventral excretory vessels measure 0.039 to 0.045 mm wide; the dorsal excretory vessels are 0.007 to 0.009 mm wide. The dorsal excretory vessels are usually dorso-lateral to the ventral excretory vessels but in some proglottids are directly dorsal. The transverse excretory vessels measure 0.006 to 0.021 mm wide. They are not easily seen in *toto* mounts. Sagittal and frontal sections show the presence of anterior and posterior (so-called secondary) branches of the transverse excretory vessels. These branches are similar to those occurring in *Cittotaenia*. Some of them extend across the proglottid to join the transverse vessel of the adjoining proglottid.

There are from 50 to 65 testes. The *Anlagen* of the testes appear in about the 30th segment. In immature proglottids the testes are ovoid with smooth margins which later become irregular in outline. The testes measure 0.030 to 0.191 mm in diameter. They are postovarian and divided by the female gland complex into a poral and aporal group. Only rarely are the two groups connected, and then by only 2 or 3 testes. The number of testes in each group is unequal. In one proglottid there were 25 testes in the poral group and 32 in the aporal group, in another proglottid there were 35 in the poral group and

* Studies from the Department of Zoology, University of Nebraska, No. 233.



Figs. 1-7. *Schizorchis ochotonae*.—1. Scolex, neck, and beginning of strobila; 2. Mature proglottid (dorsal view); 3. Female gland complex; 4. Portion of proglottid showing male and female organs (dorsal view); 5. Left half of uterus and excretory vessels (dorsal view); 6. Left half of a gravid proglottid (frontal section); 7. Pyriform apparatus with onchosphere (optical section).

All drawings were made with the aid of a camera lucida. All measurements are in mms.

Abbreviations: cs—cirrus sac, isv—internal seminal vesicle, ov—ovary, sg—shell gland, t—testes, ut—uterus, v—vagina, vt—vitellarium.

30 in the aporal group. Although the groups of testes are extended laterally, they do not reach the excretory vessels (Fig. 2). The cirrus sac measures about 0.616 mm long by 0.095 mm wide. It passes dorsal to the excretory vessels and longitudinal nerves. An internal seminal vesicle is present. The external seminal vesicle is represented by a much coiled and looped vas deferens. The cirrus is unarmed.

The crescent-shaped multi-lobed ovary is close to the anterior border of the proglottid and usually slightly poral in location. The *Anlagen* of the ovary appear in about the 7th segment. The ovary measures about 0.411 mm wide. The lobes of the ovary may or may not be secondarily branched. The glandular vagina extends ventral to the cirrus sac and dorsal to the excretory vessels and longitudinal nerves. Near its distal end the vagina curves posterior to the cirrus sac, then turns to open into the atrium ventral to the opening of the cirrus sac (Fig. 4). No enlargement of the vagina to form a seminal receptacle can be seen in mature proglottids but in gravid proglottids the seminal receptacle is represented by a distal enlargement of the vagina. The vitellarium is a lobed crescent-shaped structure located posterior and medial to the ovary. A well developed shell gland, which measures 0.041 to 0.054 mm in diameter, is located between the ovary and vitellarium. The uterus is at first tubular but with maturity develops branched anterior and posterior outpocketings. These outpocketings in the gravid proglottids are incompletely divided by parenchymal septa (Fig. 6). The uterus is anterior to the shell gland but does not reach the anterior limit of the ovary. The uterus overlaps dorsally the ventral excretory vessels in gravid proglottids only (Fig. 5). Eggs in the gravid proglottids measure 0.062 to 0.063 mm in diameter. The embryo measures about 0.015 mm in diameter and is enclosed in a well developed pyriform apparatus. The cornua of the pyriform apparatus measure 0.018 mm from the top of the embryo to the point where the cornua intersect.

Host.—*Ochotona princeps figginsi* (Allen).

Location.—Small intestine.

Type Locality.—Gunnison County, Colorado.

Syntype (= cotype).—U. S. Nat. Mus. Helm. Coll. No. 37056.

Schizorchis n. gen.

Generic diagnosis.—Small anoplocephalines. Genital pores irregularly alternate. Male and female genital ducts pass dorsal to the excretory vessels and longitudinal nerves. Transverse excretory vessels with branches. Testes numerous, located posterior to ovary and divided by the ovary, shell gland, and vitellarium into an aporal and poral group which are very rarely connected, and then by only 2 or 3 testes. Cirrus sac elongated, extending median to the excretory vessels. Cirrus unarmed. Vagina opening ventral to the cirrus sac opening. Ovary in anterior portion of proglottid and usually slightly poral in location. Uterus at first a transverse tube, later developing anterior and posterior outpocketings which are incompletely divided by parenchymal septa. The uterus in gravid proglottids overlaps dorsally the excretory vessels. Eggs

have a well developed pyriform apparatus. Adults known only from the pika.

Type species.—*Schizorchis ochotonae.* The name *Schizorchis* is from *schizo,* to split; and *orchis,* testis. Hence *Schizorchis* denotes the splitting of the testes into two groups by the female gland complex.

Discussion.—*Schizorchis* is like *Schizotaenia* in the distribution and location of testes, location of ovary, position of sexual ducts in relation to the excretory vessels and longitudinal nerves, and alternation of sexual pores. *Schizorchis* differs in location of the vagina (posterior to the cirrus sac at its distal portion and opening ventral to the cirrus sac opening), unarmed cirrus, elongated cirrus sac, and tubular development of the uterus.

Of the double-pored anoplocephalines, *Schizorchis* resembles *Cittotaenia* in the structure and extent of the cirrus sac (particularly *Cittotaenia perplexa*), in the ventral location of the vagina in relation to the cirrus sac, tubular uterus, and in the branching of the transverse excretory vessels. *Schizorchis* differs in its single set of reproductive organs, more medial location of the ovary, and unarmed cirrus.

Martin (1943) reported that of 7 Colorado pikas examined for parasites, tapeworms were the second most common parasite and fleas the most common. He found the intestine of several pikas so heavily infected that he believed food passage was retarded. No such heavy infection of pikas with tapeworms nor incidence of occurrence was found by the group working in the region of Crested Butte, Colorado. No indication was given by Martin as to the identity of the tapeworms he collected.

ACKNOWLEDGEMENT

The author wishes to thank Dr. H. W. Manter who supervised this study and made many helpful suggestions. The author also thanks G. K. Menzie, L. S. Olsen, and G. W. Kelley of the Department of Zoology, University of Nebraska, as well as J. W. McDowell of Colorado A. and M. College for the material used in this study and the data pertaining to number of pikas examined. This study was aided by funds from the Franklin E. and Orinda M. Johnson Scholarship, University of Nebraska.

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Differences in Achene Characters and Germination in Some Species of Cacalia L.

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A series of studies on development of seedlings of native plants has included *Cacalia suaveolens* L., *Cacalia atriplicifolia* L., *Cacalia Muhlenbergii* (Sch. Bip.) Fern. (*C. reniformis* Muhl.) and *Cacalia tuberosa* Nutt. The striking differences between *C. suaveolens* and the other three (considered as a group), so manifest in the mature plants, become even more so with observations on variations in the achenes, their germination, and the early development of seedlings.

In *C. suaveolens* the achenes are subcylindrical and slender, 5-6 mm. long, about 1 mm. wide, smooth (only slightly ridged in well-filled seed), shining, light brown. The germination is rapid, beginning after about 24 hours and complete within 48 hours. The cotyledonary leaves are only slightly curved on emergence.

In *C. atriplicifolia, C. Muhlenbergii,* and *C. tuberosa* the achenes are broadly ellipsoid or oblong, about 4 mm. long by 1.5 mm. wide, gummy, strongly ridged and pebbled, dull blackish-brown. The germination is slower, first noted in all cases only after 144 hours, and completed in from 4 days to 2 weeks, depending on the species. The cotyledonary leaves are strongly curved on emergence (due undoubtedly to the position of the cotyledons in the seed).

The seed used was collected at maturity in the fall and was stratified out-of-doors in flats of sandy soil until shortly before the growing season the following spring, at which time the flats were brought into the greenhouse, watered, and checked to determine the time elapsing before the start of germination, as well as the final percentage of germination.

C. suaveolens sets very little good seed and a search is necessary to find seeds which are even potentially germinable. This is not true of the other species. In all cases, however, the seed used in these studies was carefully selected and counted. In *C. suaveolens* only 77 out of 100 seeds germinated, but as these all sprouted very promptly, with no stragglers despite two months holding in the greenhouse, it is assumed that the validity of the observation on their rapid germination is not impaired, since the remaining seed seems to have been incapable of any development. Deam has observed that *C. suaveolens* has weedy tendencies, as he found it was able to invade established bluegrass sod. It seems probable that the prompt germination and subsequent very vigorous development of seedlings is likewise an expression of a weedy character.

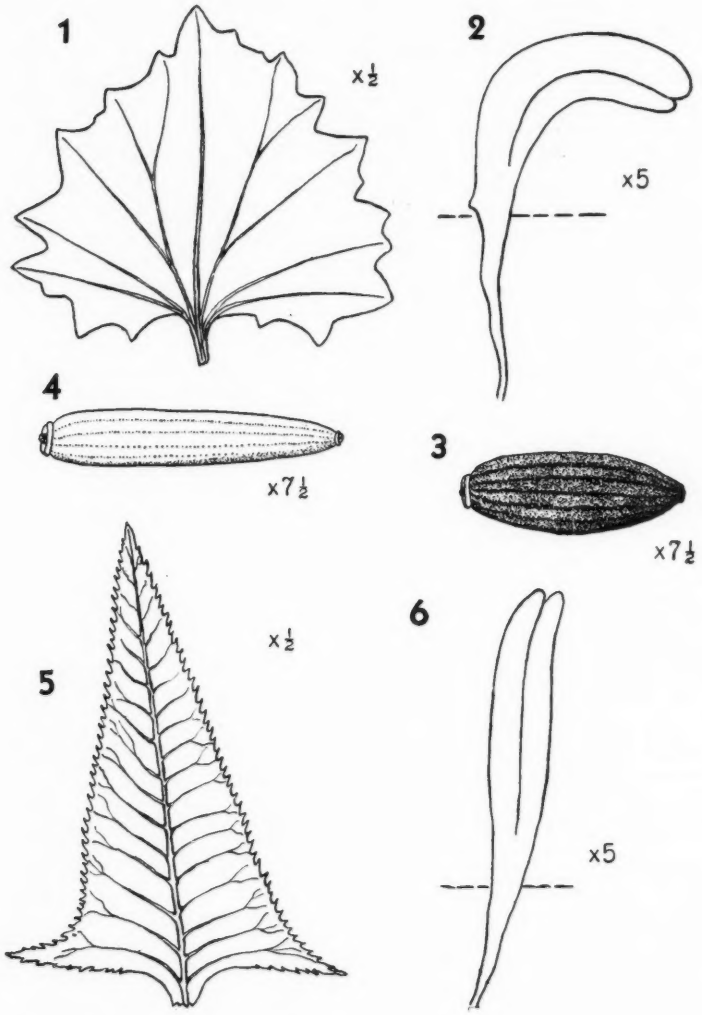

Fig. 1-3. *Cacalia atriplicifolia.*—1. Diagram of a leaf—palmate venation; 2. Diagram of a young seedling; 3. Achene.

Figs. 4-6. *Cacalia suaveolens.*—4. Achene. 5. Diagram of a leaf—pinnate venation; 6. Diagram of a young seedling.

Other notable differences between *C. suaveolens* and the other species under consideration are that in the former the receptacle is flat, there are 12-15 involucral bracts, 20-30 flowers, the lower leaves are hastate, the upper triangular-lanceolate, and all pinnately veined and strongly and even serrate, whereas in the other three species the receptacle is appendaged in the center, there are 5 involucral bracts, 5 flowers, and the palmately veined leaves are oval, subcordate to cordate, or reniform, not serrate (or if serrate not evenly so).

Rafinesque (Loud. Gard. Mag. 8:247, 1932) segregated *Cacalia suaveolens* in the monotypic genus *Synosma* Raf., and placed the other species in *Mesadenia* Raf. (New Fl. N. A. 4:78, 1836). It appears that there is considerable justification for Rafinesque's treatment, and indeed Britton and Brown (Ill. Flora 2nd ed. 3:537, 1913) recognized *Synosma* as a good genus. It seems that, at the minimum, a formal sectional subdivision of *Cacalia* is in order.

The plate which accompanies this note is offered to show the widely disparate character of *C. suaveolens*.

Notes and Discussion

The Identity of Ranunculus uncinatus D. Don

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Ranunculus uncinatus D. Don was based upon a collection in Mexico by Sessé, Mociño, Castillo, and Moldonado in 1787, 1895, or 1804, and it has not been collected in Mexico since then. A photograph of the probable type specimen and an isotype in the Field (Chicago) Museum show this plant to be the same as the West American *Ranunculus Bongardii* Greene var. *tenellus* (Nutt.) Greene. Since the epithet *uncinatus* was published earlier than any other specific epithet applied to any of the three varieties which compose *R. Bongardii* Greene, the following nomenclatorial recombinations are necessary. They are published in advance of *A Treatise on the North American Ranunculi*, which will appear in the July issue of *The American Midland Naturalist*, in order that var. *parviflorus* may be validated in time for inclusion in a forthcoming flora of Marin County, California, by Mr. John Thomas Howell of the California Academy of Sciences, San Francisco. A more detailed discussion of *Ranunculus uncinatus* and its varieties will appear in the treatise.

R. UNCINATUS D. Don var. **typicus** nom. nov. *R. uncinatus* D. Don in G. Don, Gen. Syst. Gard. 1: 35. 1831. *R. tenellus* Nutt. in Torr. & Gray, Fl. N. Amer. 1: 23. 1838, not Viviani in 1831. *R. Bongardii* Greene var. *tenellus* Greene, Erythea 3: 54. 1895. Mostly interior; Western North America as far south as California and Colorado; Mexico.

R. uncinatus D. Don var. **parviflorus** (Torr.) L. Benson, comb. nov. *R. occidentalis* Nutt. var. *parviflorus* Torr. Bot. Wilkes Exped. 17: 214. 1874. *R. Bongardii* Greene, Erythea 3: 54. 1895. Mostly coastal; Western North America as far south as California and Colorado.

R. uncinatus D. Don var. **Earlei** (Greene) L. Benson, comb. nov. *R. Earlei* Greene, Pittonia 4: 15. 1899. *R. Bongardii* Greene var. *Earlei* L. Benson, Bull. Torrey Club 68: 479. 1941. Southern Colorado and northern New Mexico.

An Unusual Form of Polygonatum commutatum

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On October 4, 1947, an unusual form of *Polygonatum commutatum* (Schultes f.) A. Dietrich[1] was collected in Dane County, Wisconsin, along State Highway 78 near its junction with U.S. Highway 12, southeast of Sauk City. At this point the highway parallels the edge of an extensive marsh.

This plant was collected because of its large size and also because several floral branches were bearing in addition to numerous berries a number of leaf-like bracts of various sizes. An examination of the specimens of *P. commutatum* in the herbarium of the University of Wisconsin showed that a similar specimen with a few bracts on some of the peduncles had been collected by Miss Irene Cull, July 1, 1945, between the towns of Hartland and Pewaukee in Waukesha County, Wisconsin. Both specimens were robust plants as indicated in the following table.

	Plant collected by Cull, July 1, 1945	Plant collected by Clarke, Oct. 4, 1947
Number of leaves on the plant	22	24
Height of aerial stem	143 cm.	169 cm.
Number of peduncles	14	15
Number of pedicels	69	89
Location of lowest peduncle	4th axil	5th axil

1 Ownbey, Ruth Peck, Ann. Mo. Bot. Gar. 31: 373-413, 1944.

The plant from near Sauk City was the only one in the locality showing the leafy bracts on the peduncles. Several other plants in the vicinity were about the same size and had about the same number of fruits.

The plants collected in 1945 and 1947 differ from *P. commutatum* forma *ramosum* described by Sister Vincent de Paul McGivney.[2] In her plants there was a branch arising from the axil of each leaf of the main aerial stem and the fruits were produced on short pedicels arising from the axils of the leaves on the lower axillary branches. The two Wisconsin specimens possess the normal type of inflorescence except that some of the lower peduncles bore a few leaf-like bracts in addition to the flowers and fruits.

Polygonatum commutatum (Schultes f.) A. Dietrich forma **foliatum**, forma nov. (Fig. 1) caulis singularis, robustis, erectis, 14-17 dm. altitudinis, glabris; pedunculis axillaribus, robustis, 2-11 pedicellis; aliquis pedunculis cum foliaceis bracteis; bracteae 1.5-6.0 cm. longis et 0.3-2.0 cm. latis.

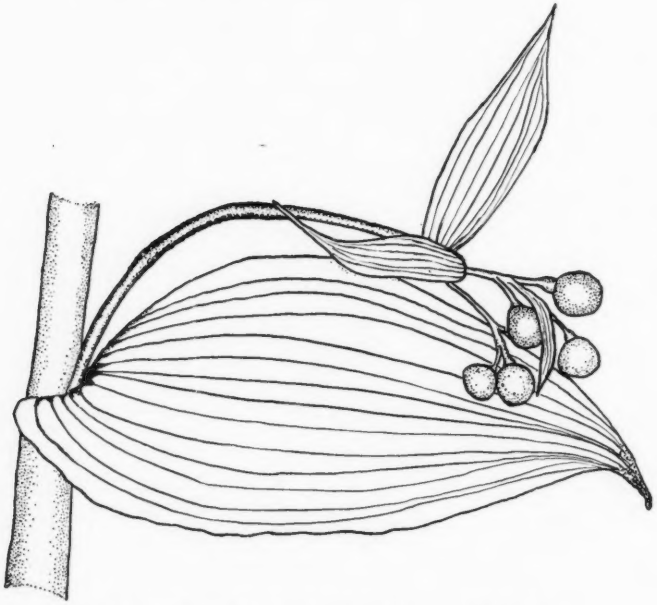

Fig. 1.—One of the lower peduncles showing the leafy bracts attached to the peduncle.

Plant with single, stout, erect stem, 14-17 dm. high, glabrous; peduncles axillary, sturdy, bearing 2-11 pedicels; this form differs from the typical *P. commutatum* in that some of the peduncles bear leaf-like bracts ranging from 1.5 to 6 cm. long and 0.3 to 2 cm. wide. — Clay soil, between Hartland and Pewaukee, Waukesha County, Wisconsin, July 1, 1945, *Cull;* roadside along margin of marsh, Dane County, Wisconsin, October 4, 1947, *Clarke*. (Type in University of Wisconsin Herbarium.)

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2 Amer. Midl. Nat. 9: 662-664, Nov. 1925.

Book Reviews

THE LAND AND WILDLIFE. By Edward H. Graham. Oxford University Press, New York. 1947. 232 pp., 32 pls., 69 figs. $4.00.

Edward H. Graham, chief of the Biology Division of the U. S. Soil Conservation Service, has written a significant book[1] in the field of wildlife conservation. In contrast to the older method of artificial propagation and the unsuccessful attempt to restore wildlife through game refuges alone, Dr. Graham advocates the modern concept of "practical wildlife management . . . accomplished through good land use." The book is of a recent hybrid-type in that it aims to meet the needs of the general reader and at the same time to be adaptable for teaching purposes. It is not a practical manual, it is not technical, and it does not give many statistics or much tabular information. It is not a research report, but it is a very readable, interesting, and instructive book. It presents a point of view ("wildlife benefits more from land management than it does from wildlife management") based upon sound ecological principles coupled with years of practical field experience in land use and its relationship to wildlife. For the general reader it explains the working principles of land use practices and justifies such procedures. For the student it bridges theoretical instruction of ecology with the application of ecology to the field of agricultural land management. This reviewer has used the book successfully as part of the required reading in a course in Conservation of Biological Resources.

In chapter I, Wildlife Heritage, the role which wild animal life has played in the life of man from his early beginnings is traced. The wild enemies of man, useful animals, animal life in art, literature, and culture are mentioned. A discussion of ancient regulations leads to chapter II, Three Centuries, which sketches briefly the history of wildlife, its management and mismanagement, from the settlement of North America to the present time. The succeeding chapters deal with specific land types, problems of their management, and their relationship to wildlife. Chapter III, First the Land, explains that "wildlife production for the most part must be a by-product of other land uses," but at the same time encourages the use of certain waste-lands primarily for game production. In agriculture lands, correlation between soil fertility and wildlife production is stressed. The next chapter, Marshes and Swamps, not only points out the value of such lands, but reviews the unfortunate tug-of-war of some years ago between the Bureau of Land Reclamation and the Bureau of the Biological Survey, and between mosquito control agencies and aquatic game management agencies. At last, an intelligent policy for the management of wet lands is expounded.

Waters are discussed only in their relation to land use, erosion, and sedimentation, as one would expect in such a book with a purposely limited scope. Chapter V, Ponds and Waters, and chapter VI, Streambanks and Ditches, stress the relationship between water conservation (including pond management) and problems of erosion. Management of aquatic resources is shown to depend upon the nature and treatment of the watershed. The following two chapters on Field Borders and Roadsides, and Windbreaks and Hedges, deal with transition habitats. The importance of the edge niche to the production of wildlife, protection of woodland, and control of cropland is explained with suggestions for establishing satisfactory habitat margins in different sections of the United States. In Gullies, Odd Areas, and Spoilbanks (chapter IX), the possibilities for utilization of such areas are pointed out, with a table of 57 species of plants which have been most successful in erosion control, including notes on the value of such plants as food for wildlife. Much of the discussion on spoilbanks centers around studies and work which have been carried out in Ohio strip mine areas. No mention is made, however, of recent legislation which requires rehabilitation of spoilbanks or of the accomplishments of the Ohio Reclamation Committee which was organized and is subsidized by the mine operators themselves.

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1 Graham, Edward H., 1947. The Land and Wildlife. Oxford University Press, New York.

Chapter X, Cropland, Pasture, and Woodlot, and chapter XI, Forests and Range, make clear that land suitable for agriculture and timber production can serve wildlife best when such lands are managed properly for their intended purposes, with wildlife a by-product which naturally results from good agricultural and forest practices. Well meant but ineffective artificial measures (winter feeding, flushing bars, etc.) for the welfare of wildlife on such lands are attacked. The concluding chapters, Wildlife Prospect; The Cost and the Harvest; and Wildlife, Land, and People; discuss the importance of wildlife, both desirable and undesirable species, to different groups of people—farmers, sportsmen, biologists, and nature lovers. Land management for wildlife production is reiterated, and it is pointed out that misuse of land is largely responsible for the increase of pest species. The economic value of wildlife is outlined briefly, with estimations of monetary returns from wildlife and its harvest. The reason cited for the protection of bobwhite quail in Ohio (worth $25 annually for eating insects), however, is oversimplified and misleading. Actually such protection is a complicated and bitter political problem which has been fought over many years. Costs of producing desirable species and controlling harmful species are discussed in light of the return from the investment. In the case of game it is brought out that the economic value is as much if not more concerned with the recreational and commercial factors of harvesting the game than with the actual utilization of the catch.

The author reduces his analysis of conservation to first principles with the statement that, "Life is much more a matter of ecology than it is an expression of economics." A plea is made for the preservation of a sample of every type of natural communities for scientific study and for a point of reference in connection with land management practices. Such is the objective of the recently organized Ecologists Union although the existence of this group is not mentioned.

Throughout the book, the close interrelationship between wildlife management and land management is emphasized with arguments for treating wildlife as a crop of the land. There are a few instances in which prejudice is shown in favor of the land managers over that of the wildlife managers. While mistakes and failures of wildlife managements are pointed out with emphasis, similar failings of land management (i.e. draining of valuable waterfowl habitats for worthless land, etc.) are sometimes explained away. There are 32 plates with a total of 69 half-tone prints, all of which are excellent and nearly all illustrate specific points of land and wildlife management. There is a bibliography of 151 titles of pertinent studies with a one-sentence annotation on the content or significance of each one. Many of these references are cited in the text, and a guide is given to some of the journals in the field of land management biology. The index is complete. The opening paragraph of the preface reads, "This book was written to make a point." This reviewer believes that the point has been well made.—RALPH W. DEXTER, Kent State University, Kent, Ohio.

TEXTBOOK OF GENERAL ZOOLOGY (Fourth Edition). By Winterton C. Curtis and Mary J. Guthrie. John Wiley and Sons, Inc., N. Y. 1947. xx+794 pp. $4.50.

Curtis and Guthrie's *Textbook of General Zoology* in the twenty years of its existence, has become one of the most popular textbooks of general zoology in the United States. The fourth edition improves on what was already an effective presentation of the best features of the "phylum" and "principles" approach to the study of zoology.

The fourth edition of *Textbook of General Zoology* retains the essential organization of the previous editions by introducing the student first to the more familiar facts of vertebrate anatomy and physiology with the emphasis on man but making comparisons with the frog in particular as the basis for laboratory study. This is followed by the study of the cell, cell division, reproduction, development and genetics. With these principles in mind the student is then allowed to become acquainted with the other phyla of the animal kingdom. Whether it is better to study the vertebrate at the end or at the beginning of the course is a question only the individual teacher can decide. Cer-

tainly both systems have their merits, and this text is so written that it could be used with equal effectiveness with either system.

In a field in which many excellent texts have been written, Curtis and Guthrie have made a distinct contribution in presenting an effective combination of scientific writing and a clear, readable style for the student who is willing to give it more than a casual perusal. There is no attempt made to avoid the use of zoological terms when they are needed. As a result the student can obtain an adequate zoological vocabulary.

The principal innovation in the fourth edition is a new chapter on the organ systems of invertebrates which is most helpful in making comparisons with vertebrates. New figures have been added and old ones improved. The text has been rewritten where necessary to bring it up to date. In organization, style, accuracy and illustration the fourth edition of *General Zoology* will find increasingly high favor in courses designed for both general and preprofessional students.—W. HENRY LEIGH, Wright Junior College, Chicago, Illinois.

ZOOLOGY THE SCIENCE OF ANIMAL LIFE. By A. M. Winchester. Van Nostrand, New York. 1947. xii+437 pp., 266 figs. $4.50.

To serve the needs of a semester's "survey" or "cultural" course, obviating the difficulties of selection from and the excessive complexity of the standard works, Professor Winchester offers a short textbook based on representative types of the major phyla. Discussion of these occupies 24 of the 31 chapters. Inserted in them are short (rather than succinct) treatments of selected principles, the rhinoceros and tick-bird, *e. g.*, appearing among the flatworms in a minimal account of parasitism, commensalism and symbiosis. The remaining chapters touch scientific method, taxonomy, "vital animal life processes," cytology, genetics, embryology and adaptation, *inter alia*.

The author's photographs, usually excellent, are well-reproduced, but not always needed, while there is an insufficiency of diagrams and drawings. Those included are in part injudiciously chosen (*e g.*, fig. 2.1, a "typical animal cell" with a heavy wall), mistaken (fig. 2.5 E, a radiolarian) or misleading (fig. 10.3, an over-simplified *Ascaris*). Source and size are not always indicated.

The text would appear to be lectures unrevised for publication from the tone of it. The author's viewpoint is anthropocentric; his animals are anthropomorphous ("nervous," "shy and retiring," "meek," "lazy," "solicitous" or, in *many* cases, "vicious"). The prose is simple in its words (eschewing the difficult *Drosophila*, *Homo*, *Rana*, etc.) and its ideas (dropping complications, as tetrads from meiosis and the first two micronuclear divisions from conjugation in *Paramecium*). Attributing of specific or generic characteristics to higher categories is so frequent as to overweigh mislabellings, misspellings and misstatements as the most serious fault of the book. Review questions, at the close of each chapter, are catechistic. The glossary is probably useful locally, the diacritical marks, pronunciations and definitions being in part peculiarly the author's (*e. g.*, "Vellum (vel'-um), a membrane found on the subumbrella surface of some jellyfish") as are some of the etymologies "Wucheria" and *Cambarus* ,"derivation unknown"; *americanus*, *Eng*(lish?), for American; *Diphyllobothrium latum*, Gr. *diphyos*, twofold + *bothrion*, sucker and L. *latus*, side; fairy-shrimp named for ability to disappear and reappear, etc.). The index is inadequate.—J. L. MOHR, University of Southern California, Los Angeles.

GENERAL BIOLOGY. By Leslie A. Kenoyer and Henry N. Goddard. Revised Edition. Harper & Bros., New York. 1945. viii+653 pp., 431 text figures, and 2 plates. $4.50.

Many teachers of general biology courses will welcome the revised edition of this outstanding textbook by Kenoyer and Goddard. It has been amplified and better illustrated and should supply abundant material for an introductory course. It is to be

commended particularly for the exercises and bibliography included at the end of each chapter.

Botany suffers less here than in most general biology texts. Of the total of 31 chapters, eight are devoted exclusively to plants, ten to general topics, and thirteen exclusively to animals. The 139 pages on plants, though brief, give a good survey of the plant kingdom. In both botany and zoology the important principles are generally well covered, and, as the authors say in the preface, they steer a median course between type study and principles methods. On the whole it may be said that the treatment of groups of organisms is more adequate than the discussion of such topics as photosynthesis, respiration, biosynthesis, rise of sap in trees, secondary growth in vascular plants, etc.

As an example of the inadequacies mentioned above, the instance regarding rise of sap on p. 88 may be cited, in which one gathers the impression that sap is pushed from below and pulled from above. Neither root pressure nor the cohesion theo. are clearly explained in the paragraph. In another case, *an instance of the conceit of* : ology, photosynthesis is introduced as an important difference between plants and animals, instead of as the most important process linking the inorganic and organic worlds. In fairness to the authors they later develop some of the important features of photosynthesis to organisms in general.

The order of presentation is designed for convenience of illustrative materials and to emphasize the interrelations of plants and animals. Seed plants, thus, are taken up early along with introductory and general features, such as cellular structure, protoplasm and metabolism. The survey of organisms is initiated with the protozoa, which are followed by chapters on the algae and fungi, multicellular animals, and higher plants.

Genetics is sandwiched between the surveys of animals and plants. At the end are chapters on evolution, ecology, and conservation, the latter being an innovation.

The book is greatly enhanced by an index and an appendix, which includes the outlines of plant and animal classifications, a glossary, a bibliography, and a list of teaching films.—NOE HIGINBOTHAM, Argonne National Laboratories, Chicago, Ill.

A CHECKLIST OF PLANTS IN THE WASHINGTON-BALTIMORE AREA. By Frederick J. Hermann. Issued by the Conference on District Flora, E. H. Walker, Chairman. Smithsonian Institution, Washington, D. C. December, 1946. Second edition, 134 pages (mimeographed). $1.40.

In 1919 there was published by the U. S. National Museum a *Flora of the District of Columbia and Vicinity*, prepared by A. S. Hitchcock and Paul C. Standley, with the assistance of other botanists of Washington. It listed 1630 native or naturalized plants and 108 waifs, obtained from an area with a radius of approximately 15 miles centered on the National Capitol. A Checklist similar to that now issued was prepared and distributed in September 1941, under the same authorship.

The two Checklists itemize the plants of a much larger area than that of the *Flora*, bounded by the Pennsylvania-Maryland border on the north, Chesapeake Bay on the east, the Rappahannock and Rapidan rivers on the south, and the east foot of the Blue Ridge Mountains on the west. This region is highly diversified and supports a greatly varied flora that in systematic interest perhaps is unsurpassed by another of similar extent elsewhere in temperate North America. It is not surprising therefore that the second edition of the Checklist has been augmented to include no fewer than 2404 species, varieties, and forms of native and naturalized Pteridophyta and phanerogams.

The first Checklist listed approximately 2170 names, and that of 1946 has 234 additions, as the result of recent intensive explorations by Washington and Maryland botanists, and of discovery of old herbarium records previously unknown or overlooked. Many of the new records result from the enlarged area covered, but probably the majority are the fruit of more thorough field work. Since Washington and Baltimore have long been centers of botanical study, and the homes of many botanists interested in the local flora, it is somewhat surprising that so great a number of additions could be

found in so brief a time in a region that presumably has been rather thoroughly explored. It is evident that local botanists of even the longest-settled parts of the United States still have opportunity for new botanical discoveries, although it must be admitted that the Washington-Baltimore area possesses greater extents of woodland and other untilled land than are found in most parts of the Central and Eastern States.

These two Checklists are to serve as a basis of a projected new flora of the region they cover. It is sincerely to be hoped that such a publication may not be delayed; but if during the next few years additions to the local flora can be made at the same rate as during the past five, a moderate delay will increase substantially the size and ultimate usefulness of the final flora.—PAUL C. STANDLEY, Chicago Natural History Museum.

NORTH AMERICAN SPECIES OF MYCENA. By Alexander H. Smith. University of Michigan Press, Ann Arbor; Geoffrey Cumberlege, Oxford University Press, London. 1947. 521 pages, 56 text figures, 99 plates. $6.00.

An important element of the Basidiomycete flora in many floristic regions of this continent consists of small saprophytic agarics, which belong in the genus *Mycena*. Alexander H. Smith's book contains a definition of the genus *Mycena*, a short history of past research on *Mycena* in North America, a valuable discussion of all diagnostic characters, a review of the accepted classification and a complete taxonomic treatment of the temperate and some subtropical species. The author divides *Mycena* into 17 sections and a number of subsections and *stirpes* which are grouped within the 4 main subgenera: *Pseudomycena*, *Eumycena*, *Glutinipes* and *Mycenella*. The majority of the tropical and subtropical and also all the excluded and doubtful species are treated in supplements which contain very interesting information on type material. The use of the *stirps* as a taxonomic entity reuniting a group of obviously closely related species has been adopted from the French mycologists. Its use in fungus-monographs, especially of large genera, has definite theoretical and practical advantages. The illustrations are plentiful and, as always in Smith's papers, excellent.

Smith's *Mycena* book is, in spite of its modest title, an original taxonomic monograph, not excluding the anatomy, chemical characters and ecology of the organisms studied, and will be invaluable to American as well as foreign mycologists. The reviewer no less than others who have been endeavoring in similar original studies can appreciate the immense amount of work that has been necessary to assemble and reassemble the innumerable facts presented in the 232 complete descriptions, the notes on various other species, the anatomical figures and the plates reproducing the author's photographs of fresh material. The author has, in earlier papers, pioneered in the cytological study of the genus *Mycena*, and has now introduced into his descriptions a very careful study of the anatomy of the various parts of the carpophores and the iodine reaction of the spore walls and tissues. His keys are very clear and can be used advantageously by discriminating, trained students.

Some taxonomists might be inclined to criticize Smith's extremely broad concept of the genus *Mycena*, a concept much broader than that of Fries and the classical school, but nearly coinciding with that of the author of a previous monograph, R. Kühner. However, in the reviewer's opinion this broad concept is a progress rather than a regress since both these monographers have noticed the affinities of the various groups combined in *Mycena sensu* Fries with species formerly dispersed all over the Agaricales, whereby it appeared impossible to separate these species generically from elements now usually considered as true Mycenas. The only alternative would have been the partition of the genus, *i.e.* the admission of several smaller genera instead of a single one, a solution which the author was not quite ready to adopt. Some remarks in the book lead one to assume that the author's aim was a monograph of the species referable to the *facies* Mycena rather than to the systematic-nomenclatural unit *Mycena*. If the reviewer has understood this attitude correctly, he is inclined to believe that Smith's conception of *Mycena* was proper in view of the personal interpretation he gave to his problem.

Another point that might perhaps be criticized is the minimizing of the microchemical characters—in this case in vivid contrast to the views of the author's predecessor, Kühner, whose classification is mainly based on differences in the iodine reaction and metachromatism in cresyl blue stains. While admitting that the iodine reaction is a character of major importance, Smith goes on to declare: "I have minimized its use . . . because of the difficulty of determining it on fresh material. It is a character of considerable value to the specialist, but one likely to be difficult for the beginner to interpret." While this point of view may be reasonable or at least defendable, the reviewer fails to see why it should have influenced questions of taxonomy and affinity. On the other hand, it must be recognized that the inclusion of certain species with unknown iodine reaction [e.gr. *Mycena minutula* (Peck) Sacc.] seems to be desirable for reasons of floristic completeness, and an emphasis on microchemical reactions would have made their inclusion impossible.

It would be unreasonable to expect that in the course of admitting or rejecting some 500 binomials, the author should have always decided in favor of a name acceptable to *all* other mycologists. For instance, the reviewer would have preferred the proposal of a few new names to somewhat precarious interpretations of European species, especially those not proved to occur in both continents. However, the author has never disregarded the International Rules, an attitude that tends to make his nomenclature less vulnerable to future readjustments than that of many other contemporary authors.—ROLF SINGER, Farlow Herbarium, Harvard University, Cambridge, Mass.

ENGLISH-FRENCH AND FRENCH-ENGLISH TECHNICAL DICTIONARY. By Francis Cusset. Chemical Publishing Company, Inc., Brooklyn, N. Y. 1946. 591 pp. $5.00.

Cusset's *English-French and French-English Technical Dictionary* is an exceedingly clear, modern dictionary. It is accurate, concise and remarkably easy to use because of the easily read bold-type consistently used throughout.

This dictionary embodies up-to-date terms in daily use and satisfies a very definite need for a good, accurate, technical dictionary. It is, of course, primarily a dictionary of industrial mechanical and general scientific terminology. It is not a biological dictionary and is not intended to be the *vade mecum* of the botanist and zoologist who will find very little use for it if they intend to use it strictly in the fields of botany or zoology.

I consider this a fine dictionary and a very handy technical adjunct to a complete French-English and English-French Dictionary. It is highly recommendable for the technical man reading French texts or reviewing French research.

Primarily it is an engineering dictionary written by an engineer for engineers.—A. L. DELISLE, University of Notre Dame, Notre Dame, Indiana.

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